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Access Intelligence

VOL. 125 NO. 9 SEPTEMBER 2018

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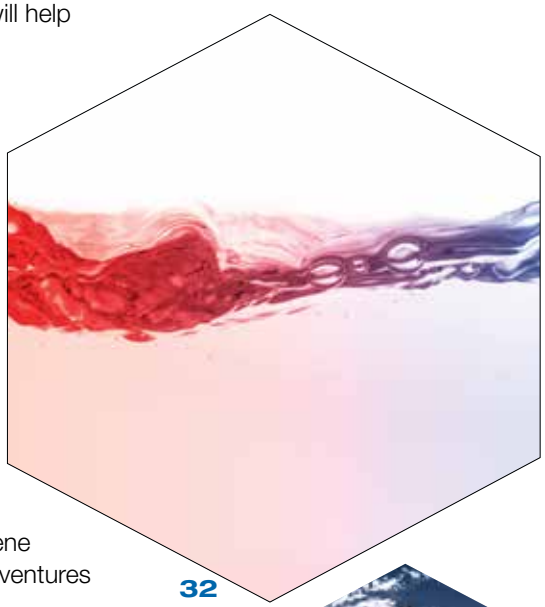

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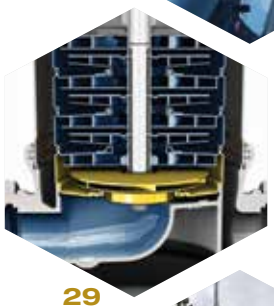

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Cover design: Rob Hudgins

CHEMICAL ENGINEERING
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Editor's Page

Focusing on the workplace

The results of a recent survey (2018 Pulse of Engineering Survey*) give a snapshot of how over 2,200 survey respondents view their current work environments. The respondents were predominantly design engineers (37%), followed by those in research and development, consulting, processing and production. The majority of respondents (64%) were seasoned professionals with more than 20 years of experience, with 42% at over 30 years of experience.

Regarding their overall career choices, working on interesting projects was cited as the most important factor by an overwhelming 87% of the respondents. And a good work/life balance came in second in importance, with a 67% vote. More than half of the respondents said that the pace of their work is constantly increasing and that they are expected to do more with less — a situation that presents challenges.

The challenges

According to the survey, engineers are feeling more pressure in their jobs, with designs becoming more complex and greater time-to-market pressures. While 78% of respondents said that they always or frequently meet quality targets, 40% also feel that pressure to meet deadlines is putting product quality at risk.

In addition to time pressures, other challenges to productivity, innovation and quality include constraints on people and resources, and a lack of talent and specialized knowledge. In fact, a constraint on resources and people was cited as being the biggest challenge, with 75% of the respondents in agreement.

Finding qualified candidates to fill positions has been a problem often cited by the chemical process industries in recent years. More and more, companies and universities are addressing the need through various programs. In Michigan, for example, Delta College (www.delta.edu), in collaboration with The Dow Chemical Company (www.dow.com) offers an accelerated 13-week program to prepare students with skills for jobs as chemical process operators.

Continued attention to the skills gap is needed to train new employees as well as to raise the skill levels of current employees, engineers and operators alike, particularly as more skills related to the shift to increased digitalization — such as for data analytics — are needed.

Knowledge

When asked how engineers maintain and advance their professional skills, the top-rated answer was through books (at 48%), followed by learning through colleagues, online training courses and webinars. When the responses were broken down to differentiate between "veteran engineers" and "millennials," there was little difference between the two groups in their responses to this question.

The importance of technical documentation was clearly noted in the survey, with 69% of respondents considering it to be the most essential tool needed to complete projects. Attention to maintaining good technical documentation, and the continuing challenges in doing so, are often mentioned in our articles**. Documentation is an area that apparently still needs improvement, and taking the time to maintain good records can save time in the longterm, and possibly help alleviate some of our workplace challenges. ■

Dorothy Lozowski, Editorial Director

* IEEE Global Spec (www2.ieeeglobalspec.com/2018pulse)
** See for example, www.chemengonline.com/pressure-relief-system-design-developments-deficiencies; and www.chemengonline.com/unrecognized-problems-relocating-laboratories

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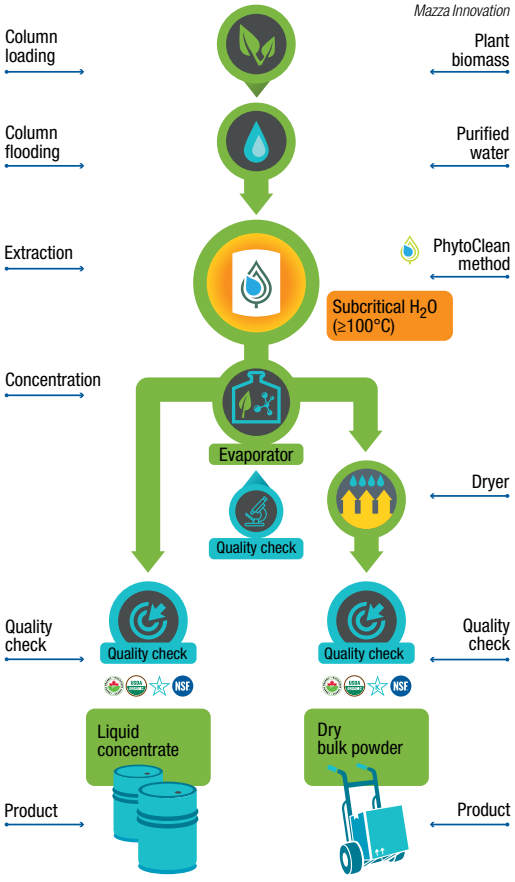
BPA

Solvent-free recovery of plant-based extracts

Plant-based extracts, such as antioxidants, phytochemicals and polyphenols, are used in a number of end-markets, including cosmetics, foods and nutritional supplements. A proprietary, low-polarity, pressurized-water extraction method is set to drastically improve the recovery of useful ingredients from botanical sources. Mazza Innovation Ltd. (Vancouver, B.C., Canada; www.mazzainnovation.com) designed the PhytoClean botanical extraction technology to be free of solvents, preservatives and excipients, making it more environmentally friendly than similar extraction technologies.

Typically, botanical extraction processes depend on hydrocarbon-based solvents, which can lead to the presence of residual solvents or carrier compounds in end products. The PhytoClean method uses only water, manipulating the polarity of water molecules to control the solubility of targeted bioactive compounds at temperature and pressure conditions where water is still a liquid but its hydrogen bonds are disrupted, enabling the concentration of bioactive compounds in the water. According to the company, this method has shown comparable or better performance with regard to processing time, selectivity and yield, when compared to traditional extraction solvents, particularly for extractions from berry pomace and leafy plants. In addition to eliminating the use of solvents, the PhytoClean method does not require that raw materials be dried or ground up prior to extraction, providing lower costs and easier material-quality validation.

Mazza Innovation is set to significantly expand the commercial reach of the PhytoClean process. The company was acquired in July by global manufacturing firm Sensient Technologies Corp. (Milwaukee, Wisc.; www.sensient.com), and signed a longterm supply



agreement with BASF SE (Ludwigshafen, Germany; www.basf.com) to develop new botanical solutions for cosmetics applications. "The BASF partnership is the largest for Mazza so far in the cosmetics area, and it provides an exciting entry into a very large untapped market for us," says Benjamin Lightburn, Mazza Innovation chief executive officer. To meet the stringent quality standards required by BASF, Mazza implemented a unique quality-control measure designed specifically for this partnership, explains Lightburn.

Edited by:
Gerald Ondrey

BIO-ISOPRENE

Yokohama Rubber Co. (Tokyo, Japan; www.yokohama.com) has developed what is said to be the world's first technology capable of efficiently producing isoprene from biomass. The new breakthrough is the result of joint research with Riken (www.riken.jp) and Zeon Corp. (both Tokyo; www.weon.co.jp).

Isoprene is a raw material in the production of synthetic rubber (polyisoprene rubber) used in automobile tires and other applications. Industrial isoprene is currently produced as a byproduct of naphtha cracking. The development of this new technology will reduce dependence on petroleum and contribute to the reduction of CO_2, a greenhouse gas.

The three partners began joint research in 2013, and in 2015, discovered a new isoprene-synthesizing process using a computer-based in-silico metabolic design technology — a technology for designing new artificial metabolic reactions on computers. Further development of this new technology has led to the creation of cells with excellent isoprene-synthesizing capability based on

(Continues on p. 8)

HF alkylation unit converted for solid-bed alkylation of LAB

In a first-of-its-kind endeavor, a hydrogen-fluoride-based alkylation unit producing linear alkyl benzene (LAB) is being converted into a solid-bed alkylation unit that employs UOP's (Des Plaines, Ill.; www.uop.com) Detal-Plus alkylation technology for LAB. LAB is used in the production of a variety of detergent formulations.

Shifting to solid-bed alkylation technology eliminates the need for acid (HF) unloading, storage, regeneration and neutralization. In addition, maintenance costs will be lower and special acid handling training procedures and personal protective equipment will be eliminated.

The project is being undertaken at the Puente Mayorga LAB plant in San Roque, Spain. The facility is owned by Cepsa (Madrid, Spain; www.cepsa.com), which also owns an adjacent petroleum refinery. UOP has completed the basic engineering on the conversion, and Sacyr Fluor will complete the detailed engineering. The goal of plant owner Cepsa is to realize a capacity expansion for LAB production. The project involves the replacement of HF alkylation process equipment with UOP's Detal Plus equipment, which is said to enable higher LAB selectivity, longer operating cycles and lower maintenance costs than alternative technologies.

The new Detal Plus unit will employ the latest generation of UOP's ZDA-30 catalyst, which further improves LAB selectivity and reduces byproducts at lower capital and operating expenses than the previous generations of Detal catalysts, UOP says.

Cepsa plans to operate the HF detergent alkylation plant until the new Detal-Plus plant is ready for commissioning in 2020.

a new artificial pathway and highly active enzymes. These engineered cells metabolize (in vivo) sugar from biomass into isoprene, which can then be polymerized into polyisoprene rubber.

It has widely been understood that isoprene is produced naturally from mevalonic acid (an intermediate substance formed from sugar) through a five-stage reaction. The new artificial pathway reduces the stages down to two. Furthermore, the highly active enzymes possess a phenomenal isoprene-producing capability that is not achievable by natural enzymes. Introducing this artificial pathway and these enzymes into colon bacilli enhances the isoprene-generating ability that the bacteria lack in nature. Yokohama Rubber has confirmed that this technology can also be applied to butadiene-based synthetic rubber and other diene rubbers.

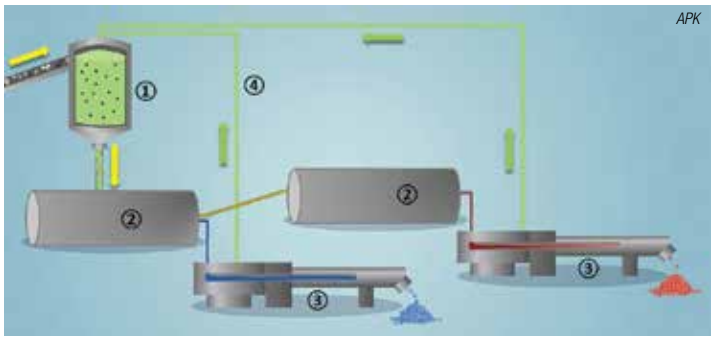
P-RECOVERY

The recovery of phosphorus from wastewater-treatment facilities is not only important for operational maintenance and cost reduction, but is also key to preventing agricultural runoff into adjacent water bodies. Technology from Ostara Nutrient Recovery Technologies Inc. (Vancouver, B.C.; www.ostara.com) is capable of recovering phosphorus from wastewater streams and transforming the nutrient into a high-purity agricultural fertilizer (*Chem. Eng.* February 2013, pp. 17–22). The Ostara process is most cost-effective with ortho-phosphate concentrations of at least 70–100 mg/L. Some industrial applications have concentrations in the range of 2,000–5,000 mg/L or higher. The Ostara process recovers greater than 90% of phosphorus at higher concentrations and 70–75% at lower concentrations.

The company has now added a new step, known as WASSTRIP (waste-activated sludge stripping to

(Continues on p. 9)

Solvent-based process recycles multilayered film



Later this year (Q4 2018), APK AG (Merseburg, Germany; www.apk-ag.de) will start up the first commercial plant to recycle multilayer packaging using the company's solvent-based Newcycling process. The plant will process 8,000 metric tons per year (m.t./yr) of post-industrial multilayer film waste into pure, sorted polyethylene (PE) and polyamide (PA) re-granulates (approximately 2/3 PE and 1/3 PA). Because the quality of the products is similar to virgin resins, granulate from the Newcycling process can be reused in applications such as flexible packaging.

In the Newcycling process (diagram), PE/PA multilayer films are first shredded into flakes. The flakes are fed to a bath (1) containing a solvent that dissolves PE, enabling the PA to be mechanically separated (2). The solvent is recovered (4) and reused, and the two product streams are then extruded and pelletized (3).

Alternative mechanical recycling methods, which consist of shredding, washing, density sorting and extrusion, are unable to handle multilayer films, so such waste has typically been incinerated or recycled into lower-quality granulate suitable for low-value applications, such as pallets. In contrast, the Newcycling process results in a much higher-value recycling of the films, producing granulate close to virgin material, says the company. By proper selection of the solvent used, other film laminates can also be recycled, such as polypropylene (PP) and flexible PP (fPP), and other plastics are under development.

APK is planning a second plant that will handle a minimum of 25,000 m.t./yr of post-consumer plastic waste, with startup planned for the end of 2020. APK is also involved in a number of additional projects: A joint-development project with Henkel (Düsseldorf, Germany), Mondi Group (Vienna, Austria) and Borealis AG (Vienna, Austria) to replace virgin low-density PE (LDPE) by LDPE re-granulates from Newcycling process; a cooperation agreement with Royal DSM (Heerlen, the Netherlands) for recycling PE/PA6 film; and a strategic partnership with MOL Group (Budapest, Hungary) to further support the commercialization of the technology.

CNT-based photocatalysts enable solar water splitting

Splitting water with sunlight is a sustainable and environmentally friendly way to make hydrogen, but the conversion efficiency is presently very low, because current photocatalysts only work using ultraviolet radiation — a small fraction (3–5%) of sunlight. Now, a promising photocatalyst that operates over a much broader wavelength range has been developed by the research group of Yutaka Takaguchi at Okayama University (Japan; www.okayama-u.ac.jp), in collaboration with Yamaguchi University and Osaka Shinyaku Co., Ltd. (Yamaguchi, Japan).

The photocatalyst consists of dye-encapsulated single-walled carbon nanotubes (SWCNTs). The CNTs absorb the longer wavelength light (600–1,300 nm), which enhances the efficiency of the photocatalyst activity. A ferrocene-type organic pigment is encapsulated inside the SWCNTs and supports the efficient absorption of longer wavelength light. The researchers fabricated a coaxial, three-component heterojunction (dye, SWCNT and C_{60}). Despite the larger diameter (≈1.4 nm) of the SWCNTs relative to that set by Flavel's rule (0.95 nm), the photoinduced electron transfer from dye-encapsulated SWCNTs to C60 proceeded smoothly, resulting in the photosensitized evolution of H_2 from H_2O, using a ferrocenyl-based photosensitizer. At irradiation of 650 nm (red), this photocatalyst was found to be 120 times more efficient compared to other systems. An 8–9% conversion efficiency was observed at 500–550 nm, compared to the 1–5% efficiency of alternative photocatalysts.

Osaka Shinyaku plans to sell the two new pigments, which can be applied from solution as a coating of sheets, for producing H_2. The catalyst system could be commercialized within three years.

Making windows multifunctional

Concern with energy efficiency has increased the popularity of window glass coatings that control the amount of sunlight that passes through, as well as windows made of thin solar cells that can turn them into electricity generators. Now researchers from South China University of Technology (Guangzhou, China; www.scut.edu.cn), led by professors Hin-Lap Yip and Fei Huang, have combined those two functions.

The researchers had to perform a three-way balancing act between harvesting light for electricity generation, blocking some of the light for efficient heating, and allowing normal transmission through the window. To do this, they developed a dual-function semitransparent organic photovoltaic (ST-OPV) device that is highly efficient and also very effective for heat insulation. A non-fullerene acceptor was introduced with enhanced near-infrared (NIR) absorption and distributed Bragg reflectors for selectively enhancing the transmittance of visible wavelengths while maintaining high reflectance for NIR.

According to the researchers, the ST-OPV devices generate over 6% power conversion efficiency with high visible light (more than 25%) transmission and an outstanding IR-rejection rate of more than 80%. In theory, the researchers say, installing windows outfitted with dual electricity-generating and heat-insulating capacity could cut an average household's reliance on external sources of electricity by more than 50%.

"We have not even used the best organic photovoltaics available," says Yip, adding that their efficiency is improving rapidly. This is only the beginning of exploring new applications of organic photovoltaics, continues Yip. "A version tailored for self-powered greenhouses is only one of many impactful products that we want to develop in the future."

remove internal phosphorus), to augment the nutrient-recovery process. The process has been implemented in multiple facilities in North America and Europe. A facility will begin construction later this year at the Cielcza Sewage Treatment Plant in Jarocin, Poland.

NATURAL PRESERVATIVE

Scientists at Nanyang Technological University (NTU; Singapore; www.ntu.edu.sg) have discovered a plant-based food preservative that is more effective than artificial preservatives. The preservative contains naturally occurring flavonoids, a diverse group of phytonutrients found in almost all fruits and vegetables. The flavonoids created by NTU scientists have strong antimicrobial and anti-oxidant properties; two key traits of preservatives that inhibit bacterial growth and keep food fresher for longer.

In tests carried out on meat and fruit juice samples, the organic preservative kept its samples fresh for two days without refrigeration (23°C). In contrast, the food samples with artificial preservatives succumbed to bacteria contamination within six hours.

The findings were published in a recent

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issue of *Food Chemistry*. The researchers are in talks with multinational companies to further develop the new food preservative.

FCC CATALYST

The Catalyst Div. of BASF SE (Ludwigshafen, Germany: www.catalysts.basf.com) has launched a new generation of fluid catalytic cracking (FCC) catalysts for gas-oil feedstock. Tradenamed Fourte, the new catalyst is based on BASF's new multiple framework topology (MFT) technology, and has been optimized to deliver "superior selectivity" to butylenes, while maintaining catalyst activity, which helps refineries maximize their profits, says BASF.

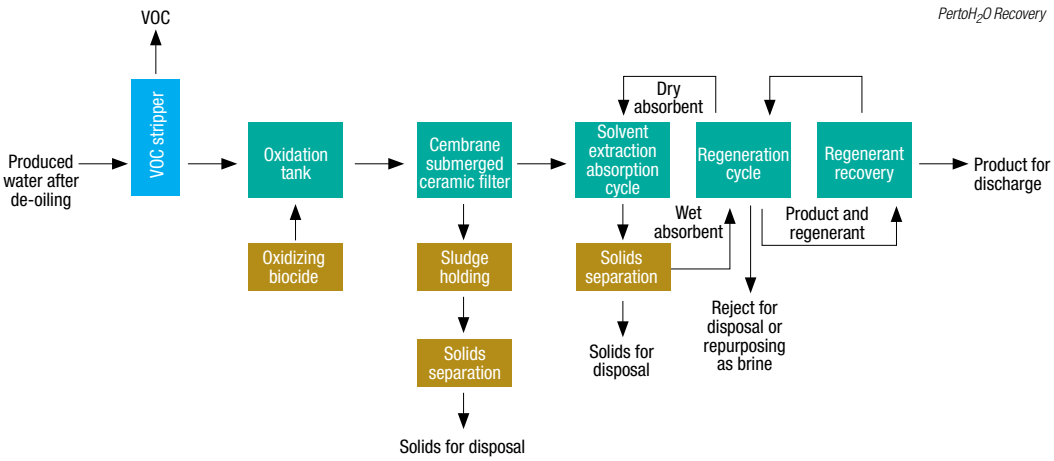
MFT technology enhances performance through the use of more than one framework topology that work together to tailor the catalyst selectivity profile. Evaluations of the new MFT technology have demonstrated Fourte's ability to help maximize margins and provide operating flexibility to make more butylenes to feed the alkylation unit.

SNG FROM SEWAGE

Ineratec GmbH (https://ineratec.de), a spinoff of Karlsruhe Institute of Technology (KIT; Germany; www.kit.edu), and Naturgy Energy Group S.A. (formerly Gas Natural Fenosa; Barcelona, Spain; www.naturgy.com) are working towards closing the CO_2 cycle. In Sabadell, Catalonia, the partners built a pilot plant that produces synthetic natural gas (SNG) from the reaction of renewable H_2, which is made by electrolysis, with CO_2 from biogenic sources, such as sewage sludge.

The pilot plant at Sabadell will produce 100 m^3/d of SNG, and uses a catalyst developed by the Catalonia Institute for Energy Research (IREC; Barcelona; http://cerca.cat) for the conversion of CO_2 from biogenic sources. The plant is part of the Spanish project Synthetic Fuels — Combustibles Sintètics (CoSin), which is funded by the European Regional Development Fund. ❑

Non-thermal treatment method for high-salinity produced water



A new pilot project brings together advanced membrane filtration with non-thermal, zero-liquid-discharge (ZLD) solvent exchange to efficiently treat high-salinity produced water from oil-and-gas operations. PetroH2O Recovery (Southlake, Tex.; www.petroh2o.com) is currently building a pilot plant with the capacity to process 20 barrels per day of produced water from an operating well in the U.S. The plant will employ Cembrane submerged flat-sheet membranes for pretreatment and a proprietary ZLD extraction technology developed by Aquafortus Technologies (Auckland, New Zealand; www.aquafortus.com) for water recovery.

The Aquafortus technology involves liquid-to-liquid crystallization in a two-stage solvent-exchange unit equipped with patented absorbent and regenerant media. The absorbent encourages rapid crystallization of any salt content in the wastewater stream, effectively replacing the thermal evaporators and crystallizers used in traditional processes. In tests using actual waste streams from commercial sites, the continuous technology crystallized out all of the salts in the brine stream, allowing for the recovery of clean water for surface discharge. Typically, treatment methods for water with high total dissolved solids (TDS) consume large amounts of energy, but this non-thermal recovery technology does not.

"Current tests and modeling show this technology requires 60–70% lower operating expenses per barrel of water than current thermal processes," says Brent Waller, managing partner at PetroH2O Recovery. Further contributing to energy economics is the Cembrane's submerged operation, which enables it to operate at vacuum conditions, thus eliminating the pumping step required for pressurized membranes, explains Waller. The ceramic membrane is specially constructed to enable an "outside-in" filtration principle, and the membranes are designed to be modular and stackable so that capacity can be expanded as needed. According to Waller, the group plans to build additional pilot units at higher capacities and will announce details later this year.

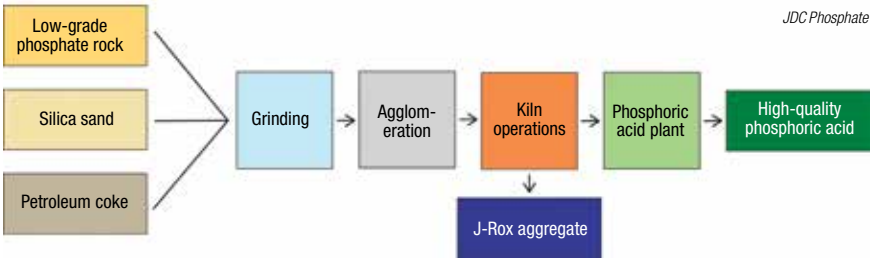
CO_2-to-methanol

Researchers from Penn State University (State College, Pa.; www.psu.edu) and Dalian University of Technology (Dalian, China; www.dlut.edu.cn) have improved the process of converting carbon dioxide into methanol by using a catalyst that combines copper and palladium. Using a palladium-to-copper atomic ratio range of 0.3 to 0.4, the combination yields the most efficient conversion of carbon dioxide to methanol observed to date. Nanoparticles of the catalyst are dispersed on a porous support material to greatly increase the surface area of the catalyst.

According to the researchers, the new formulation increased the rate of methanol formation by three times over the rate with palladium alone and by four times the rate with copper alone. The combination of the two metals lowers the energy requirements for the reaction of carbon dioxide and hydrogen, and also alters the reaction pathways to produce more methanol with higher energy efficiency.

The reaction takes place in a packed-bed reactor operating at 180 to 250°C. The maximum conversion is 24% in a single pass, but the unconverted CO_2 and H_2 are recycled and returned to the vessel.

New phosphoric acid process expands available resources



JDC Phosphate

Almost all phosphoric acid is produced via the wet-acid process (WAP), which requires relatively pure raw materials and produces large volumes of a potentially hazardous, special waste called phosphogypsum, which is highly regulated in terms of storage and disposal. A typical WAP operation will produce around 5 tons of phosphogypsum per ton of phosphate in phosphoric acid.

JDCPhosphate Inc. (Fort Meade, Fla.; www.jdcphosphate.com) has demonstrated its Improved Hard Process (IHP) for producing high-quality phosphoric acid, which not only avoids the production of phosphogypsum, but also enables the use of much lower-grade ores (13–14% phosphate content versus the 28% or more required for WAP). "The wet-acid process simply doesn't work that well if the impurities in the phosphate rock are too high, things like iron, magnesium, aluminum and so on," explains Timothy Cotton, CEO of JDCPhosphate. Furthermore, phosphoric acid produced via WAP requires various levels of upgrading, depending on the end use. "We can use more of the phosphate rock than the wet-acid process allows. We can't overstate how important it is for the phosphate industry to widen the parameters of acceptable phosphate rock from what is currently used in the wet-acid process," he adds.

IHP is a kiln-based process where raw materials are ground, mixed and agglomerated into feed balls with petroleum coke and clay, similar to iron-ore processing. The balls are then run through a rotary kiln, where a series of reduction and oxidation reactions pull elemental phosphorus out of the balls, converting it to phosphate. The phosphate is then captured in a hydration unit where it is absorbed into water, resulting in high-quality phosphoric acid. Once the phosphate content is removed, the processed balls are a co-product (mostly hard calcium silicate) that can be used as a construction aggregate. JDCPhosphate runs a demonstration plant that can process about 100 kg/h of feed. Recently, the company successfully produced high-quality phosphoric acid from a low-grade ore that contained just 14% phosphate and included high levels of impurities like silica and magnesium oxide. The company plans to continue upgrading this facility to validate an even wider range of phosphate ores and further scale up the operation. ■

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Plant Watch

Asahi Kasei to install alkaline-water electrolysis system for Toshiba Energy

August 13, 2018 — Asahi Kasei Corp. (Tokyo, Japan; www.asahi-kasei.co.jp) received an order from Toshiba Energy Systems & Solutions Corp. (Kanagawa, Japan; www.toshiba-energy.com) for a 10-MW single-unit alkaline-water-electrolysis system to be installed at the Fukushima Hydrogen Research Field. Integrated with a large-scale solar-power plant, the electrolysis system will form a core part of the Fukushima Hydrogen Research Field, which is scheduled for test operation in late 2019 and startup in the summer of 2020.

Invista begins work for world-scale adiponitrile plant in China

August 8, 2018 — Invista (Wichita, Kan.; www.invista.com) has begun engineering work to build a new plant in China using its latest adiponitrile technology. The new plant would have a minimum production capacity of 300,000 metric tons per year (m.t./yr), with an estimated investment in excess of $1 billion. Construction is targeted for 2020 and production would begin in 2023.

ExxonMobil starts up ethane cracker in Baytown

July 27, 2018 — ExxonMobil Corp. (Irving, Tex.; www.exxonmobil.com) commenced operations at its new ethane cracker at the company's integrated Baytown complex. The new 1.5-million-m.t./yr cracker will provide ethylene feedstock to new performance polyethylene (PE) lines at the company's Mont Belvieu plastics plant, which began production in the fall of 2017.

BASF plans ethylene oxide capacity expansion in Antwerp

July 24, 2018 — BASF SE (Ludwigshafen, Germany; www.basf.com) plans to pursue a significant capacity expansion of the integrated ethylene oxide complex at its *Verbund* site in Antwerp, Belgium. The project includes capacity expansions for ethylene oxide and for several downstream derivatives, such as surfactants. The final investment decision is expected to be made in 2019.

Shintech to build an integrated PVC plant in Louisiana

July 24, 2018 — Shintech Inc., a subsidiary of Shin-Etsu Chemical Co. (Tokyo; www.shinetsu.co.jp), began construction for a new integrated plant to produce polyvinyl chloride (PVC) from salt in Plaquemine, La. The new plant will be capable of producing 860,000 m.t./yr of vinyl chloride monomer, a raw material of PVC, and 660,000 m.t./yr of caustic soda. The project will increase PVC capacity by 290,000 m.t./yr.

Oxea starts up propanol plant in Texas

July 20, 2018 — Oxea GmbH (Monheim am Rhein, Germany; www.oxea-chemicals.com) has successfully started up its new world-scale propanol production unit at its Bay City, Tex. site. The unit has capacity to produce 100,000 m.t./yr of propanol. The fully operational unit will increase Oxea's North American production capacity for *n*-propanol by 75%.

New PP plant opens at Socar's Sumgayit petrochemicals complex

July 20, 2018 — Maire Tecnimont S.p.A. (Milan, Italy; www.mairetecnimont.com) and Socar Polymer (Baku, Azerbaijian; www.socarpolymer.az) officially opened a new polypropylene (PP) plant at Socar's petrochemical complex in Sumgayit, Azerbaijan. The new PP plant has a capacity of 180,000 m.t./yr. Also currently under completion at the site is a high-density PE plant with 120,000 m.t./yr capacity.

Mergers & Acquisitions

PTTGC and Mitsui enter joint ventures for PTA and PET production

August 13, 2018 — PTT Global Chemical (PTTGC; Bangkok, Thailand; www.pttgcgroup.com) and TOC Glycol Co. (TOCGC), a subsidiary of PTTGC, plan to sign joint venture (JV) agreements with Mitsui Chemicals, Inc. (MCI; Tokyo, Japan; www.mitsuichem.com) to cooperate in managing Siam Mitsui PTA Co. (SMPC), a purified terephthalic acid (PTA) producer, and Thai PET Resin Co. (TPRC), a polyethylene terephthalate (PET) resin producer. PTTGC and TOCGC will hold 74% of the shares in SMPC and TPRC, while Mitsui Chemicals will hold 26%.

Saudi Aramco, Air Products and ACWA Power to form $8-billion JV

August 13, 2018 — Saudi Aramco (Dhahran, Saudi Arabia; www.saudiaramco.com), Air Products (Lehigh Valley, Pa.; www.airproducts.com) and ACWA Power (Riyadh, Saudi Arabia; www.acwapower.com) have signed agreements to form an over $8-billion gasification and power JV located at Jazan Economic City in Saudi Arabia. The JV will purchase the gasification assets, power block and the associated utilities from Saudi Aramco for over $8 billion. These assets are currently under construction and will be transferred to the JV upon successful startup, currently scheduled for 2019.

Indorama acquires French plastics recycler Sorepla Industrie

August 8, 2018 — Indorama Ventures Public Company Ltd. (IVL; Bangkok, Thailand; www.indoramaventures.com) entered into an agreement to acquire Sorepla Industrie S.A., a plastics recycler in France. Sorepla operates a

52,000-m.t./yr facility consisting of three production lines: recycled PET; recycled high-density polyethylene (rHDPE); and food-grade pellets.

Ascend Performance Materials to acquire Netherlands-based plastics compounder

August 8, 2018 — Ascend Performance Materials, LLC (Houston; www.ascendmaterials.com) purchased Britannia Techno Polymer (BTP), an engineering plastics compounder based in the Netherlands. BTP specializes in the production of proprietary nylon compounds.

Lanxess plans to sell remaining 50% stake in Arlanxeo to Saudi Aramco

August 8, 2018 — Lanxess AG (Cologne, Germany; www.lanxess.com) plans to sell its remaining 50% stake in synthetic rubber JV Arlanxeo (Maastricht, the Netherlands; www.arlanxeo.com) to its JV partner Saudi Aramco. The parties expect to complete the transaction by the end of 2018. The JV is valued at €3.0 billion. Lanxess expects to receive approximately €1.4 billion from the transaction.

Ingevity to take full ownership of Purification Cellutions joint venture

July 25, 2018 — Ingevity Corp. (North Charleston, S.C.; www.ingevity.com) signed an agreement to acquire the remaining 30% of Purification Cellutions, LLC (Waynesboro, Ga.) from its partner Applied Technology Ltd. Partnership. The purchase price is approximately $80 million. Purification Cellutions manufactures honeycomb scrubbers used for vapor-emissions control.

Celanese to sell ethanol plant, form JV with Chengzhi

July 20, 2018 — Celanese Corp. (Dallas, Tex.; www.celanese.com) intends to sell its Nanjing ethanol unit to Chengzhi Shareholding Co., along with all related assets, including equipment, storage tanks and pipelines. This agreement also concerns the formation of a JV surrounding Celanese's TCX ethanol-production technology. The companies are also planning to restart the Nanjing unit as soon as possible, likely in 2019.

AkzoNobel acquires peroxides manufacturer in Brazil

July 20, 2018 — AkzoNobel Specialty Chemicals (Amsterdam, the Netherlands; www.akzonobel.com) finalized an agreement to acquire Brazilian firm Polinox, a producer of ketone peroxides. The sale is expected to close in late 2018. The company will acquire Polinox's Brasnox, Perbenzox and TecnoxSuper brands. AkzoNobel will invest to add capacity in its own site at Itupeva, Brazil and transfer operations there after the expansion.

Borealis acquires plastics recycler in Austria

July 18, 2018 — Borealis Group AG (Vienna, Austria; www.borealisgroup.com) has signed an agreement for the acquisition of 100% of the shares in plastics recycler Ecoplast Kunststoffrecycling GmbH. Based in Wildon, Austria, Ecoplast processes around 35,000 m.t./yr of post-consumer plastic waste from households and industrial consumers, turning them into polyethylene recyclates. ■

Mary Page Bailey

Creating Custom Chemistry for Oil-and-Gas Production

The complex demands of oil-and-gas production often require the development of customized chemical technologies, and CPI companies are rising to meet these challenges

IN BRIEF

ADAPTING CUSTOMIZED CHEMISTRIES
ENHANCING OIL RECOVERY
APPLYING NANOTECHNOLOGY
TREATING WATER
IMPROVING FLOW

The oil-and-gas and chemical process industries (CPI) are interconnected in that the oil-and-gas sector provides many of the raw materials that are the backbone for chemical manufacturing. However, the CPI also supplies many essential products for oil-and-gas production (Figure 1), from corrosion inhibitors to water-treatment chemicals and much more. As drilling and recovery technologies evolve, and market and regulatory demands place increased pressure on operators, CPI companies are developing technologies that are tailored to the needs of the oil-and-gas sector.

FIGURE 1. A unique aspect of producing chemicals for the oil-and-gas sector is that CPI companies have developed methodologies to tailor products for a customer's specific situation

Adapting customized chemistries

Due to the wide variety of complex chemistries encountered across the breadth of oil-and-gas operations, Clariant AG (Muttenz, Switzerland; www.clariant.com) has been able to leverage technologies used in different specialty chemicals segments to benefit oil-and-gas producers. "Customers aren't paying for chemistry, they are paying for problem-free production," said Jon Rogers, global head of Clariant Oil Services at an event inaugurating upgraded blending and analytical facilities in Clinton, Okla. Rogers mentioned that Clariant has adapted specialty technologies used in the company's pigments and personal-care product lines to create tailored solutions for oil-and-gas customers. Jonathan Wylde, head of innovation at Clariant Oil Services, further underlines this point with the example of glucamide, a sugar-based surfactant: "For instance, glucamides were originally developed for personal and homecare applications, such as dishwashing soap, hand soap and laundry detergent, and due to the superior surfactancy of this chemistry platform, applications in enhanced oil recovery were realized due to the ability of the glucamide chemistry to release oil from a rock surface." Another example of this phenomenon includes Clariant's adaptation of agrochemical technology into demulsifier products that lower the surface tension of oil and water, thus allowing coagulation of oil and its ultimate separation from water.

One of the most important factors in developing effective oilfield-chemical products is to understand that a user's region and production method may bring with them very specific concerns. Clariant's Clinton, Okla. site (Figure 2) is well suited to handle the particular production needs of shale processers in the U.S. Mid-Continental region. "This region contains a wide variety of production issues, from corrosion and scale to emulsions and paraffin. The issues are specific to each oilfield," explains Kevin Wilson, regional laboratory manager at the Clinton site. "The high-grade instrumentation at the new laboratory allows for the efficient and accurate processing of oilfield samples," he continues. The laboratory includes capabilities for Fourier-transform infrared spectroscopy (FTIR), as well as X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses, all in close proximity to users' assets. Wilson cites an exam-

Clariant

FIGURE 2. Advanced analytical techniques are being applied to adjust products for regional production trends, including the presence of paraffins or oxygen in gas streams

ple where the Clinton site formulated a fit-for-purpose corrosion inhibitor that could tackle not only common corrosive agents like carbon dioxide and hydrogen sulfide, but also oxygen, relatively uncommon and difficult to treat in large quantities. "Oxygen poses a very high corrosion risk when present inside pipelines or surface production equipment. This particular customer had oxygen in their transmission lines without the ability to remove or block the oxygen contamination," explains Wilson. The challenge was exacerbated since the amount of oxygen was too high for a traditional scavenger product, so an inhibitor to block the interaction of oxygen at the metal surface was the best option. The final inhibitor formulation included known corrosion inhibitors to target CO_2 and H_2S, as well as other additives to inhibit and passivate the abundant oxygen.

H_2S is another troublesome species — not only is it corrosive, but it is also highly flammable and toxic. A common method for treating H_2S is to use triazine scavengers, but triazine can introduce serious production issues. For instance, the high pH of triazine can cause the precipitation of calcium carbonate scale, and once the triazine is spent, it can

Kemira

FIGURE 3. Specialized injection equipment helps to ensure the longterm integrity of polymers used for enhanced oil recovery

become insoluble, creating downstream transmission issues, says Wilson. Furthermore, polymeric byproducts and amine release can create problems with corrosion, product contamination and low-temperature solidification. Clariant has developed a non-triazine-based H_2S scavenger to address some of these concerns. "The pH of the non-triazine scavenger is closer to neutral, which prevents precipitation of pH-dependent species," explains Wilson.

Beyond H_2S scavenging, other issues plague shale production, including paraffin-containing gas streams, which can plug tubing and cause failures. "Over the last three years, the industry transitioned from the production of light, sweet, and easy-to-treat crude oil towards more complex combinations containing paraffinic components. This switch has resulted in an unprecedented increase in paraffin-related challenges," explains Wylde. This evolution is pushing chemists to apply more advanced analytical techniques to characterize crude oil, since heavier paraffins are not detectable using traditional methods. These newer characterization methods include nuclear magnetic resonance (NMR) and matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF), which can detect paraffin chains in excess of 100 carbons in length and determine a tri-modal distribution of paraffin in crude oil. "Clariant is currently undergoing work to elucidate the structural performance relationships between paraffin inhibitors and crude oils containing these higher paraffin species," adds Wylde.

For deepwater applications, one of the major concerns is the control of gas hydrates, which are complex "ice-like" structures formed at high pressures and low temperatures that can potentially block critical subsea flow lines that otherwise would transport the hydrocarbon fluids and gases from the subsea wellheads. "Typically, gas hydrates are controlled using low-dose hydrate inhibitors that allow the uninterrupted production of oil and gas. These chemistries are required at relatively high concentrations," says Wylde. However, he says that Clariant is developing a solution for tackling gas hydrates that works at much lower (parts per million) concentrations.

Linde

FIGURE 4. Combining injection of gases (such as nitrogen or carbon dioxide) with nanoparticles enables more rapid oil recovery

Enhancing oil recovery

Clariant's Wylde mentions that chemical-enhanced oil recovery (CEOR) is another trending area. In CEOR, polymers are injected into an oil reservoir to increase production through the displacement of oil by injected water from the reservoir. Furthermore, surfactants can be co-injected in order to increase the sweep efficiency by lowering capillary forces in the reservoir rock and allowing otherwise trapped oil to be more effectively "washed" off the rock surface. Clariant's Hostafrac line of products for shale CEOR features a surfactant backbone manufactured from sustainably sourced raw materials, including a sugar-based hydrophilic head and a lipophilic tail based upon coconut oil, says Wylde. Furthermore, the products are biodegradable, do not have a propensity to bio-accumulate and have been specially formulated to be free of benzene, toluene, ethylbenzene and xylenes (BTEX), as well as volatile organic compounds (VOCs).

In response to growing interest in CEOR, Kemira Oyj (Helsinki, Finland; www.kemira.com) is currently executing an expansion project in Botlek, the Netherlands to increase production capacity for polyacrylamide polymers used in CEOR, and recently signed a multiyear supply agreement with Chevron North Sea Ltd. The Botlek expansion is due to come onstream in 2019.

"Polyacrylamide flooding is a widely used CEOR method that injects water containing high-molecular-weight polyacrylamide polymers into the reservoir to improve sweep efficiency. The polymer increases the viscosity of the injection water, improving the mobility ratio between the water and the hydrocarbon trapped in the reservoir. The polymer solution migrates through the reservoir from the injection well to the producing well and 'sweeps' the oil in the reservoir into production," explains Pedro Materan, senior vice president of Kemira's global oil & gas business.

Some users may employ CEOR as a measure to improve recovery from an aging reserve once primary and secondary recovery methods have been exhausted, while others may design their fields to implement CEOR upon startup. For this reason, it is important that chemical providers are involved throughout the project lifecycle in order to tailor a solution to meet unique customer needs, considering many factors, including reservoir permeability, temperature, brine composition and oil-in-place viscosity. "Our early involvement in these projects ensures that our research and development teams can build a polymer aligned with the reservoir conditions that will deliver optimum performance when it reaches the field," says Materan. And al-

though laboratory analysis enables evaluation of a number of important polymer performance properties, such as filterability, viscosity, chemical and thermal tolerances and injectivity, the success of a CEOR polymer treatment goes beyond developing the chemistry in a laboratory. "The initial investment in polymer development can be lost without the correct field application," says Materan. Kemira has developed specialized equipment for polymer dissolution and injection (Figure 3), which help to ensure that polymer integrity is maintained throughout injection and subsequent processing steps.

As operating companies are more willing to invest in polymer CEOR, Materan believes that the technology will continue to advance, enabling developers to broaden the operating range into more challenging environments, such as those with extreme temperatures or higher-salinity brines, and to better understand the long-term effects of these conditions on polymers, since they may be exposed to reservoir conditions for months or even years. "Projects previously deemed uneconomical can be revisited as viable development options. We are seeing this globally as new applications areas are being identified by existing and new CEOR operators. Newer regions, including Canada, India and South America are opening up to CEOR opportunities," he adds.

Applying nanotechnology

In July, Linde LLC (Bridgewater, N.J.; www.lindeus.com) and Nissan Chemical America Corp. (Nissan Chemical; www.nissanchem-usa.com) unveiled the new Recharge HNP well-enhancement technology at the Unconventional Resources Technology Conference (URTeC) in Houston. The technology is the first to combine established gas-driven well-enhancement methods with nanoparticles. "It's combining two chemistries that are known independently to help improve hydrocarbon recovery. We're putting them together in downhole applications for stimulation or enhanced recovery because they work synergistically," says Robin Watts, Chemistry & Energy program manager at Linde. Nitrogen or CO_2 is used to drive Nissan Chemical's nanoActiv HRT nanoparticles deep into a well where they can increase liquid flow by altering wettability and entering tiny fractures and pores in the formation that would otherwise be impenetrable using traditional technologies. "The nanoparticles are solid, so when you inject them downhole, they don't work on a chemical basis, they work on a mechanical basis," adds Watts.

Each nanoparticle is specially coated to encourage it to repel against other nanoparticles in solution, inducing Brownian motion. "Once in Brownian motion, when the nanoparticles approach a droplet attached to a surface, they will start working through disjoining pressure to release the droplet off the surface. This is very complementary to the mechanism of the injected gas to release and recover hydrocarbons,"

explains Watts. She emphasizes that pumping gases like CO_2 downhole with the nanoparticles synergistically helps to push the particles further into the well than previously possible, while CO_2's miscibility in downhole applications lowers viscosity and helps to introduce more hydrocarbons to the wellbore, providing hybrid benefits. "The technology is able to reach in and grab hydrocarbons that were not recovered using primary methods," she continues. Furthermore, the technology is simple to implement in that it requires no special equipment and works very quickly. "With traditional Huff n' Puff (HNP) enhancement processes, after injection, you must close up the well and soak it for some time, anywhere from a week to a month, and then you can start flowing back the well. With Recharge HNP, we usually only recommend 36 hours of soak time since the nanoparticles act so quickly," mentions Watts. She emphasizes that this type of enhancement is especially important in unconventional wells where primary methods may typically recover just 3–7% of reserves.

The technology was commercially trialed with an operator's existing horizontal wells in the Austin Chalk and Buda formations in Texas. The operator originally was considering injecting a small amount of nitrogen for secondary recovery, but the addition of nanoparticles along with gas showed promising response. This trial also showed strong correlation between the wells' response and the treatment dosage, indicating that the solution could be tuned for specific downhole scenarios. For instance, dosage concentration can be altered for wells with extensive amounts of downhole water, and Nissan Chemical has also developed nanoparticle grades specifically for water-sensitive or high-temperature applications.

Treating water

From seawater at offshore exploration sites to the water injected into hydraulic fracturing (fracking) reservoirs, handling large volumes of water is an essential part of oil-and-gas production, and invariably, this water will require some form of processing or treatment. Microbial contamination in fracking water is a major concern for operators in this sector. "When microbes grow, they form a biofilm that can plug fractures and limit hydrocarbon production, along with corroding equipment through microbially influenced corrosion. In addition to negatively impacting asset integrity and production rates, microbes also produce H_2S, which has the potential to sour valuable hydrocarbons," says Christina Pampena, regional marketing manager for Europe and North America for the Dow Chemical Company's Microbial Control division (www.dowmicrobialcontrol.com).

Microbial control chemicals, such as biocides, can be applied to mitigate the growth of harmful bacteria and other microorganisms, but it is important that fracking operators understand how microbial control solutions work throughout a project's lifecycle. According to Ken Wunch, energy technology leader at Dow Microbial Control, an effective biocide program should apply targeted combinations of chemistries to address specific site conditions during the different phases in hydraulic fracturing, from preparing the water through decontaminating the well to protecting the reservoir. For instance, initially preparing water with a quick-kill biocide like 2,2-dibromo-3-nitrilopropionamide (DBNPA) will help to cut down on the initial bioload of the water and enhance the performance of biocides used in later stages. "Designing a tailor-made microbial-control program requires technical and regulatory expertise. Countries and regions manage product regulations governing the use of biocides differently," explains Wunch. The specific geologic conditions of a region, basin or individual formation may also dictate the optimal dosage level for each biocide, so an effective biocide program must consider factors like downhole temperature, water quality, compatibility with other fracking additives and the desired duration of control. For example, to tackle extreme environments, Dow Microbial Solutions is launching winterized versions of two of its biocide formulations that are designed to not freeze, even at temperatures as low as –40°C. "These chemistries are especially effective in controlling slime-forming bacteria and sulfate-reducing bacteria in oil-and-gas operations," adds Pampena.

While operators may be tempted to adopt low-cost, fast-acting microbial treatments, such as chlorine dioxide (ClO_2) or tributyl tetradecyl phosphonium chloride (TTPC), Wunch suggests that applying such solutions alone may leave assets at risk for biofouling, corrosion and souring, since they will react quickly and lose efficacy downhole, as well as corrode equipment and potentially react with other completion additives, promoting the generation of toxic byproducts. Non-oxidizing biocides, such as those containing glutaraldehyde, also provide rapid control of microbes without corrosion risks, says Wunch. Furthermore, he explains, preservative biocide chemistries, such as tris(hydroxymethyl)nitromethane (THNM) or dimethyl oxazolidine (DMO), can be combined with glutaraldehydes to further enhance long term treatment efficacy if needed, since THNM and DMO's heat stability enables them to perform effectively in a reservoir for several months.

Improving flow

Much work has gone into understanding the flow behavior of hydrocarbons during all phases of operations. Proppants are solid media — typically sand or ceramic particles — used to keep subsurface fractures open and aid flow. Hexion Inc. (Columbus, Ohio; www.hexion.com) has introduced an additive to address concerns with proppant flowback, which is when oil carries proppant materials out of the fracture along with oil. This phenomenon can cause fractures to shrink and can damage pumps and surface equipment. Flowback is increasingly concerning as longer lateral fracture lengths are necessitating more intense proppant injection. Also, proppants may often require specialty coatings to enhance their performance in certain applications. Earlier this year, Hexion introduced the industry's first mobile coating plant for proppants — enabling in-basin resin coating services and improved logistics. There is no doubt that chemical technologies like proppants will continue to evolve apace with oil-and-gas production demands. ■

Mary Page Bailey

Improved Pump Solutions Keep Product Moving

New pump technologies offer better containment and reliability to keep product flowing safely and efficiently

IN BRIEF

ENSURING CONTAINMENT
REDUCING COST OF OWNERSHIP
CHALLENGING APPLICATIONS

Because moving hazardous or high-value product through the process in a cost-effective manner is the name of the game in today's chemical process industries (CPI), ensuring containment, reliability and efficiency is crucial when pumping materials in challenging chemical applications. To help processes run optimally, pump manufacturers aim to provide pumps that offer leak-free, reliable operation.

"Reliability is the number one thing processors are looking for," says John Hall, strategic market manager with Viking Pump, Inc. (Cedar Falls, Iowa; www.vikingpump.com). "Unplanned shutdowns for pump maintenance are unacceptable, so we're continually working to build greater reliability into our pumps, with higher strength or harder materials, longer-life bushings and bearings and better shaft sealing systems," Hall says.

Wanner Engineering

FIGURE 1. The Hydra-Cell T100 Series high-pressure triplex pumps are packing-free and designed to replace horizontal centrifugal pumps and packed plunger pumps in oil-and-gas applications

Ensuring containment

Because chemical and emissions containment are key to running a profitable operation and ensuring compliance with environmental and safety regulations, pump manufacturers strive to offer a variety of solutions that make pump leakage a non-issue.

"Shaft sealing is always an issue," says Hall. "Simple sealing techniques like packing require some leakage. Mechanical seals prevent leakage, but may require external support systems that add complexity. Sealless magnetic drives prevent leakage and don't need external support systems, but are expensive. So it comes down to what system best supports the processor's needs in terms of emissions, their operations personnel and the liquids being handled."

Because containment is not a one-size-fits-all issue, pump manufacturers continue to improve sealing and sealless technologies that address leakage. For example, Viking's Universal Series of internal gear pumps, which are the company's main chemical-pump product line, offer a variety of sealing options, including a double-O-ring seal, component seals, cartridge seals and sealless magnetic (mag) drives. The sealless mag-drive option eliminates the shaft seal to provide high levels of liquid and vapor containment, as all liquid and vapor are hermetically sealed in the pump. These pumps are designed especially for hazardous and difficult-to-seal liquids.

In addition, the company frequently develops special solutions for unique applications, and can then apply them to the broader chemical market, says Hall. "For instance, we developed a unique double-o-ring sealing system for pumping chocolate, and are now looking at chemical applications to eliminate leakage from pump packing glands."

The sealing system features an O-Ring Seal Bushing with two sets of O-rings to seal food-grade grease (for handling chocolate) in the bushing area. This prevents migration of the pumped material along the shaft and keeps it in the pump. The bracket bushing is

Netzsch

FIGURE 2. Netzsch offers pumps in a wide range of materials to meet some of the most demanding chemical applications. For abrasive slurries, the company can also supply the wear components of the pumps with coatings, such as tungsten carbide coating, to increase the life of the pump

lubricated by clean grease for long life and requires no special clearances. O-ring seals are tolerant of abuse and require no periodic re-tensioning like packing does. They exhibit strong abrasion resistance and can handle most viscosities. And, unlike lip seals, which are designed for low pressures, O-rings can tolerate very high pressures.

Goulds Pumps (Seneca Falls, N.Y.; wwww.gouldspumps.com), too, is improving its seal technology to prevent leakage. "We found that 70% of pump downtime is tied to failure of the mechanical seal, which manifests itself as a leak, so we've had a significant focus on optimizing the seal chamber environment in the area where the mechanical seal sits," says Stan Knecht, vice president and general manager of industrial products. One of the outcomes is the Taperbore Plus seal chamber, which addresses the most common reasons for seal failure — inadequate heat dissipation and poor lubrication. The Taperbore Plus technology allows the mechanical seal to run cooler with better face lubrication. It also keeps solids, air and vapors away from the seal faces, further extending seal life. It is an enlarged seal chamber, allowing increased radial clearance between the mechanical seal and the chamber, providing better liquid circulation and improving heat removal.

Sealless pumps are also being improved upon for better containment. "Since so many chemical-based raw materials and finished products, such as acids, caustics and solvents, can be dangerous to handle — or are produced in explosive atmospheres — it is imperative that pumps used in these processes are leak free and can offer full containment," says Christophe Jovani, marketing communications manager with PSG, a Dover Company (Oakbrook Terrace, Ill.; www.psgdover.com). "The most effective way to achieve reliable product containment is through a sealless design. That's why many of PSG's product brands have developed sealless versions of their products, with safe and reliable use in demanding chemical processing applications the ultimate goal."

GEA

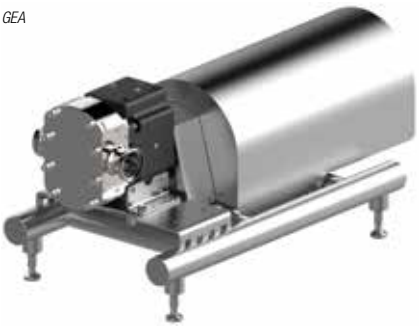


FIGURE 3. The Hilge Novalobe 60 was designed for pumping and dosing highly viscous media, also with large particles. The new Novalobe can pump larger quantities at low speeds while ensuring that emulsions and sensitive materials do not separate during pumping

Specifically, all models of Almatec and Wilden air-operated double-diaphragm (AODD) pumps and Abaque peristaltic pumps, due to their traditional design and method of operation, are sealless. Blackmer offers the SMVP Series pumps, which feature a magnetic coupling. "The stainless-steel SMVP Series Sliding Vane Pumps feature a sealless magnetic coupling that enables them to meet the need for zero leakage when handling expensive, hazardous and hard-to-seal fluids," says Jovani. "The pumps use standard samarium-cobalt magnets that prevent magnet degradation if adverse operating conditions are encountered. Also, their self-lubricating, carbon-graphite sleeve bearings ensure no metal-to-metal contact and allow for limited dry-run operation."

And, building off its sealless diaphragm Hydra-Cell pump technology, Wanner Engineering, Inc. (Minneapolis, Minn.; www.hydra-cell.com) extended the product line to include the Hydra-Cell T100 Series high-pressure pumps (Figure 1). "The T100 Series triplex pumps are packing-free and designed to replace horizontal centrifugal pumps and packed plunger pumps in oil and gas applications," says Donelle Capriotti, business development director, with Wanner Engineering. Featuring a sealless, multiple-diaphragm design, the pumps eliminate hazardous volatile organic compound (VOC) emissions along with cleanup and disposal costs of packed-pump leakage. The design also eliminates the need for external lubrication and maintenance, as well as plunger wear problems associated with packing. "These are the first triplex diaphragm pumps able to run at the flow and pressure rates normally handled by packed plunger pumps in the petrochemical, oil and gas industries," says Capriotti. "They rely on hydraulically balanced diaphragms to handle high pressures and are great in these applications because they keep pumped fluids from leaking. This is important because these industries are fined for emissions and typically have to build expensive secondary containment areas around other pumps. These pumps don't require that."

Reducing cost of ownership

"Many productivity achievements are driven through the cost of total ownership, which can include improving efficiency of processes, but also reducing maintenance and operating costs, as well as increasing reliability of pumps," says Goulds' Knecht. For this purpose, Goulds developed PumpSmart technology, which provides advanced pump control protection and optimized logic designed to prevent failures, improve pump reliability and maximize the flow economy of process systems by using a standard variable-frequency drive (VFD) with pump-specific algorithms embedded directly into the drive. "The pump controlling software enables users to change the design of their operating systems, leveraging

Sundyne

FIGURE 4. Ansimag pumps have no seals to replace, which means there are no leaks and no emissions. The pumps are also designed to streamline maintenance requirements and increase plant uptime

ITT Bornemann

FIGURE 5. Using a magnetic coupling, the SLW is a hermetically sealed, twin-screw pump used in the chemical and petrochemical sectors because it is environmentally friendly

variable-speed technology, allowing them to reduce the lifecycle energy costs of their pumps by 30 to 40%, in many cases," says Knecht.

Goulds I-Alert 2 equipment health monitor was also developed to help increase reliability and reduce total cost of ownership, he says. The health monitor combines Bluetooth and sensor technology to allow monitoring and diagnostics from a safe distance via a cell phone application (app). It provides continuous machine monitoring through early detection of failures, vibration, temperature and run-time monitoring, data logging with trend analysis, advanced vibration analysis tools and instant access to machine records. "This allows users to get quantitative data and analyze their pumps," says Knecht.

PSG has been working to improve the design and operation of their pumps and related technologies in order to increase reliability and efficiency, says Jovani. One example is the recent development of Wilden's Pro-Flo Shift air-distribution system (ADS). "A historic shortcoming in the operation of AODD pumps has been the loss of air, or energy, at the completion of the pump stroke," he

Viking Pumps

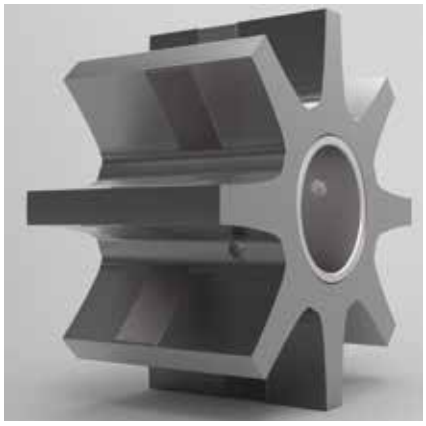


FIGURE 6. A recent addition to Viking's Universal Seal range features a modified ribbed/stepped idler gear design. Removing 0.9 mm of material from 80% of the flank of each idler gear tooth on both sides results in reduced gear-to-gear contact that could damage tiny sugar crystals or other solids in the pumped fluid

explains. "The Pro-Flo Shift features a unique air-control spool that eliminates this 'over-pumping' at the stroke's completion, resulting in optimized air usage that can be as much as 60% less than competitive models."

Also helping to increase reliability of pumps is selection of the proper material, says John Dean, U.S. Business field manager, chemical, pulp & paper with Netzsch (Exton, Pa.; www.netzsch.com/us). "Because the chemical industry has many demanding applications that involve the pumping of corrosive chemicals, one of the biggest challenges in selecting the right pump is determining what the best material of construction is for the pump," he says. "Depending on how aggressive and corrosive the chemical is, the pumps may need to be supplied with anything ranging from 316SS, Duplex SS, Hastelloy, titanium or other metals and Buna, Viton, Teflon or other elastomers. For abrasive slurries and products, it is also important to size the pump and select the right materials for abrasion resistance" (Figure 2).

Challenging applications

In addition to the need for containing leaks and increasing reliability, the CPI are also fraught with difficult applications that require pumps designed to handle the challenges.

One such example is GEA Group AG's (Düsseldorf, Germany; www.gea.com) Hilge Novalobe rotary lobe pump. It was designed specifically for viscous media and for applications where gentle pumping or dosing is required. "The pumps are used mostly for highly viscous media, but, because they can operate at very slow rotations and speeds, they have very low shear, so they are also used for media that is not that viscous, but is sensitive to shear forces," says Ulla Fraemke, product manager with GEA.

The company has recently expanded the Novalobe line to include larger pumps. "We realized we needed to have a larger pump to accommodate the larger equipment used in processes, as well as to provide the ability to operate it even more slowly to pump more sensitive products," she explains. The Hilge Novalobe 60 (Figure 3) was designed for pumping and dosing highly viscous media, that may also contain large particles. The chamber volume was nearly doubled to 2.1 L per revolution and can pump particles measuring up to 41 mm. The new Novalobe can pump larger quantities at low speeds while ensuring that emulsions and sensitive materials do not separate while pumping.

A year of successfully field-testing the Novalobe 60 in a sugar factory confirmed its strengths in daily operation. Fraemke says production managers at the factory found it easy to operate the pump, and that wearing parts could be replaced without any retrofitting. The internal mechanical seals can be replaced from the front without removing the pump and the seals are lubricated and cooled optimally, extending the product lifetime.

Meanwhile, Sundyne (Arvada, Colo.; www.sundyne.com) also has developed pumps for challenging applications in the CPI. Its Ansimag sealless magnetic drive pumps (Figure 4) are finding use in the difficult production of chlor-alkali products, says Colin Guppy, chemical and industrial business unit leader. Because pumps are needed at each stage of the chlor-alkali manufacturing process to introduce catalysts and to move hazardous chemicals onto the next stage, plastic-lined pumps used for this application must eliminate emissions and leakage for worker safety and environmental protection. For this reason, sealless pumps are the preferred choice in these applications. The Ansimag pumps have no seals to replace, which means there are no leaks and no emissions. The pumps are also designed to streamline maintenance requirements and increase plant uptime. Ansimag pumps provide replacement options for aging ASME/ANSI B73.3 and ISO 2858 sized pumps, because the line covers a range of sizes and standard external dimensions to facilitate sealless or sealed pump replacement without changing piping or baseplates.

And, for applications where there are variations in the materials being pumped, Goulds' ITT Bornemann recently released the SLW pump (Figure 5). Using a magnetic coupling, the SLW is a hermetically sealed, twin-screw pump used in the chemical and petrochemical sectors because it is environmentally friendly. The sealed chamber means critical media with harmful substances are confined to the pump and not released into the environment. The twin-screw technology allows high viscosity fluids and fluids with variations to be more ideally pumped due to the positive displacement technology (versus centrifugal), says Knecht.

A recent addition to Viking's Universal Seal range — a widely used positive displacement internal gear pump — features a modified ribbed/stepped idler gear design (Figure 6). This pump has been specifically developed for sugar processing, but is finding use in applications where there are crystals in the pumped fluid. Removing 0.9 mm of material from 80% of the flank of each idler gear tooth on both sides results in reduced gear-to-gear contact that could damage tiny sugar crystals or other solids in the pumped fluid. "The special modification prevents crushing of growing sugar crystals in sugar mills and is finding chemical applications in preventing damage to microencapsulated products in herbicides and phase-change materials in polyurethanes," says Hall. ■

Joy LePree

Flow Measurement & Control

A flowmeter for biopharmaceutical processes

The Flexmag 4050 C (photo) is said to be the first electromagnetic flowmeter with a biocompatible, disposable flow tube specifically developed for single-use biopharmaceutical applications, including filtration processes, chromatography or buffer and media preparation. Featuring extremely high accuracy and factory calibration that eliminates the need for in-situ calibration, the Flexmag 4050 C includes a biocompatible and gamma-sterilizable disposable flow tube. As an electromagnetic meter, the Flexmag 4050 C will not drift over time, says the company. It provides completely stable, direct and accurate volumetric flow measurement, unaffected by fluid properties, such as color or density. All wetted materials comply with FDA/USP Class VI and ISO 10993, and are manufactured in an ISO 13485 certified site within an ISO 7 cleanroom environment. — *Krohne, Inc., Peabody, Mass.*
www.us.krohne.com

This meter optimizes air flow control in blowers and dryers

The installation of ST50 Series Flow Meters (photo) in the process control loops of industrial air blower and dryer systems provides highly accurate hot-air flowrate monitoring. The use of mass flowmeters ensures precise rates of flow measurement and totalized flow measurement for zone control and overall system operational efficiency. With the ST50 meter, there is no need for temperature sensors, flow computers or other devices required with orifice plates, Venturis, Vortex shedding and other flowmeters. The ST50's unique design also provides built-in temperature compensation for reliable measurement over a wide temperature range (0–250°F) with almost no pressure drop. The ST50 measures air, compressed air or nitrogen from 0.75 to 400 standard feet per second in line sizes from 2 to 24 in. Flowmeter accuracy is up to 1% of reading, 0.5% of full scale, with repeatability of 0.5% of reading. The turndown ratio is up to 100:1. — *Fluid Components International, San Marcos, Calif.*
www.fluidcomponents.com

Cover all air, gas, water and steam applications

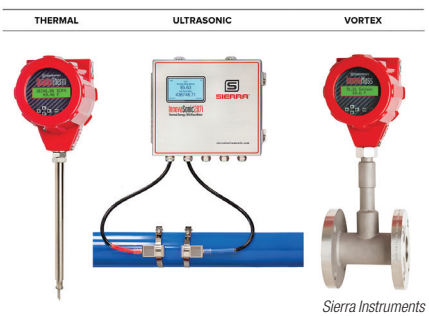
The QuadraTherm 640i/780i thermal flowmeters, the InnovaMass 240i/241i vortex flowmeters, and the new InnovaSonic 207i ultrasonic flowmeter (photo) make up the tradenamed "Big-3" flow-measurement product range. The Big-3 share the same Raptor firmware and many of the same software applications. This common firmware and software eases integration, setup and serviceability, enabling operators to leverage their knowledge between the different platforms. All patented Big-3 (thermal, vortex, and ultrasonic) sensors provide unparalleled accuracy, extensive flow knowledge through multivariable functionality, and benefit from the Raptor operating system to manage sensor inputs. They are a complete flow energy solution for measuring flows of compressed air, natural gas, steam, and hot and chilled water. — *Sierra Instruments, Inc., Monterey, Calif.*
www.sierrainstruments.com

Diagnostics for flowmeter measurement confidence

Advanced Smart Meter Verification diagnostics (photo) deliver realtime intelligence and calibration of Coriolis and magnetic flowmeters for a complete process overview and greater operational certainty. The latest version of this software provides flowmeter verification on demand and empowers process engineers, technicians and operators to look beyond the meter and make realtime decisions based on advanced meter and process diagnostics. New tools in the Smart Meter Verification software allow users to fine-tune and adjust their engineering processes to ensure absolute measurement confidence. In addition to onboard diagnostics, Smart Meter Verification also accelerates implementation of companies'

Krohne

Fluid Components International



Sierra Instruments

Emerson

Note: For more information, circle the 3-digit number on p. 74, or use the website designation.

Endress+Hauser

Brooks Instrument

SignalFire Wireless Telemetry

Bronkhorst High-Tech

industrial internet of things (IIoT) strategies with its powerful remote diagnostics, digital intelligence and multiple data points, providing users with a complete process overview and greater operational certainty. Rather than costly and time-consuming calibrations and laboratory testing, leading to production interruptions, shutdowns and safety concerns, the advanced Smart Meter Verification provides in situ calibration verification on demand without any impact on process or meter outputs. — *Emerson, St. Louis, Mo.*
www.emerson.com

A vortex flowmeter for energy management

The Prowirl 200 vortex flowmeter (photo) measures mass and energy flow of wet, saturated and superheated steam, as well as gases, liquids and cryogenic fluids, at temperatures from –328 to 752°F and pressures up to 3,625 psi. The flowmeter measures virtually every steam flow parameter of interest, making it suitable for use in industrial, building, utility and power-generation applications. The Prowirl 200 measures volume flow, mass flow, flow velocity, corrected volume flow, energy flow, heat-flow difference, calculated saturated steam pressure, steam quality, condensate mass flow, Reynolds number and temperature. It also has three totalizers. The unit's flow computer calculates mass flow, heat flow, energy flow, density and specific enthalpy from the volume flow, temperature and pressure measurements, all based on international standard IAPWS-IF97 (ASME steam data). Outputs are 4–20 mA with HART, Profibus PA or Foundation Fieldbus, plus a pulse, frequency or switch output. — *Endress+Hauser, Inc., Greenwood, Ind.*
www.us.endress.com

This transmitter uses Foundation Fieldbus protocol

A new Foundation Fieldbus transmitter has been added to this company's MT3809 variable area (VA) flowmeter (photo), making it easier for users to integrate the unit into their automation control systems for more efficient data capture and digital communication across the plant enterprise. The MT3809 metal-tube VA flowmeter is designed for extreme conditions in chemicals, petrochemicals, oil-and-gas and other applications. The Foundation Fieldbus transmitter is a compact microprocessor device that interfaces directly with the MT3809 flowmeter. A single two-wire bus connection compliant with the international Foundation Fieldbus standard provides power to the transmitter and communications access. The flowmeter itself does not require power. The new transmitter makes it easier to access multiple MT3809 VA flowmeter variables, including: flowrates, totalization (both resettable and inventory measurement), temperatures, densities, calibration factors and high-low alarm parameters, which enable facilities and systems operators to be notified if gas or fluid flowrates fall outside set values. — *Brooks Instrument, Hatfield, Pa.*
www.brooksinstrument.com

Field display of flowrates possible with wireless totalizer

This Intrinsically Safe Wireless Flow Totalizer (photo) connects to industry-standard inductive turbine flowmeters (such as the AW-Lake TW Turbine) to measure, locally display, wirelessly transmit and archive flow measurements. Data and diagnostics are available locally using the display, as well as remotely from a SignalFire Gateway using Modbus standard protocol. Enhancing new or existing turbine meters with wireless data management capabilities, the Flow Totalizer is ideal when an operator must check flowrates or totals in addition to tracking data in a SCADA system. For example, when offloading a tank, a local technician can use the Wireless Flow Totalizer to measure before and after totals of pumped fluid. — *SignalFire Wireless Telemetry, Hudson, Mass.*
www.signal-fire.com

This mass flow controller compensates for pressure

El-Flow Prestige (photo) is this company's newest generation Mass Flow Meters/Controllers for gases. It can now be equipped with an onboard pressure sensor. In combination with the company's Differential Temperature Balancing sensor technology and an incorporated gas database with physical properties, the instrument automatically compensates for inlet pressure variations. As a result,

the accuracy and control stability will not be affected by these pressure changes. The multi gas / multi range functionality of the El-Flow Prestige enables the user to select any of the installed gases and to adjust the measuring range within the boundaries of the device. Also, the dynamic behavior of the mass flow controller can easily be tuned onsite by adjusting the controller speed parameters. These settings can be changed using free software tools FlowTune or FlowPlot. FlowPlot can also be used for device diagnostics or alarm and counter settings. — *Bronkhorst High-Tech B.V., Ruurlo, the Netherlands*
www.bronkhorst.com

This flowmeter is certified for H_2 custody transfer

KEM Küppers Elektromechanik

The TCMH 0450 High Pressure TRICOR Coriolis flowmeter (photo) is said to be the world's first MI-002 / OIML137 certified Coriolis flowmeter for hydrogen-dispensing applications. By securing this certification, the TCMH 0450 can now be used in custody transfer applications — specifically in hydrogen dispensing stations for the fast-growing hydrogen-powered vehicle market. By using the TCMH 0450 flow meter, companies can sell hydrogen fuel to end users with taxation. Flowmeters in hydrogen dispensers must operate at high pressures (up to 1,050 bars), and tolerate extreme and rapid temperature changes, says the company. — *KEM Küppers Elektromechanik GmbH, Karlsfeld near Munich, Germany*
www.kem-kueppers.com

This insertion transmitter is easy to install and operate

The Insertion Electromagnetic Flow Transmitter, Series IEF (photo, is an adjustable insertion flowmeter that accurately and reliably measures fluid velocity, as well as provides several continuous signal outputs. This Series is specifically designed to offer superior performance paired with simple installation and use. One unit is adjustable to fit pipe sizes from 4 to 36 in. on most pipe materials with integrated glycol-concentration compensation. It offers several output options, including: selectable BACnet MS/TP or Modbus RTU over two-wire RS485, as well as standard analog, frequency and alarm outputs. The easy-to-use setup display guides the installer through a step-by-step wizard configuration process to suit an assortment of applications. A unique process connection collet allows for the unit to easily be installed or removed when the flow system is pressurized with the use of a full-port valve. — *Dwyer Instruments, Inc., Michigan City, Ind*.
www.dwyer-inst.com


Dwyer Instruments

This flowmeter has multi-gas functionality

The intelligent digital DPM precision multi-parameter gas flowmeter (photo) is designed to measure mass flowrates, pressure, and the temperature of clean, non-corrosive process gases. The unit's user-defined mixture functionality allows the user to create and store up to 20 custom gas mixes with up to five different gases each. The DPM allows on-site selection of 30 different local gases via the optional OLED/joystick interface or remotely via the RS-232/RS-485 or optional Modbus RTU interface. The device has a flow accuracy of ±(0.5% output reading + 0.2% full scale) at calibration temperature and pressure, a 200-to-1 turndown ratio and a 10-ms response time. — *Aalborg Instruments, Orangeburg, N.Y.*
www.aalborg.com

Aalborg Instruments

Siemens

ATC Diversified Electronics

Big changes to made to a small Coriolis meter

The low-flow FC MASS 2100 and FC300 sensors in line sizes 1/16 to 1/2 in. (photo) offer enhanced features, such as advanced programming wizards, automatic dual-phase flow filtering, flow batching and programmable dosing recipes all in a Class 1 Div. 1 enclosure with the FCT030 and FCT010 top-line digital transmitters. With this major enhancement to the product line, a broad range of users from chemical to automotive applications can benefit from mass-flow accuracy of 0.1%, density accuracy of 0.5 kg/m^3 and 100 Hz digital update rate. The high-speed update rate ensures the highest precision for applications such as the filling of beverage bottles. Already available in sizes 1/2 to 3 in., the Sitrans FCS400 sensor program has now grown to include sizes 4 and 6 in. sensors. The FCS400 features a robust frame almost immune to process noise with a wide array of process connectors for many of the standard, 3A hygienic and hazardous applications. — *Siemens Corp., Washington, D.C.*
www.usa.siemens.com

Liquid-level pump controller ensures smooth flowrates

To help municipal water, wastewater and sewage-treatment plants meet their flow-control needs, this company has introduced its new LPC series liquid level pump controller (photo). This eight-pin, plug-in conductive unit uses two probes to sense tank level and lets users select the mode of operation. In drain mode (pump down), the output relay picks up and the LED turns on when liquid reaches the high-level probe. The relay drops out and the LED turns off when liquid falls below the low-level probe. In fill mode (pump up), the output relay picks up and the LED turns on when liquid falls below the low-level probe. The relay drops out and the LED turns off when liquid reaches the high level probe. — *ATC Diversified Electronics, Newell, W.Va.*
www.marshbellofram.com

Gerald Ondrey

New Products

A new valve series for extreme conditions

The new 190 Series (photo) of control and shutoff valves features dye-forged pressure-containing parts (valve housing and bonnet), guaranteeing a homogeneous material structure without any discontinuities. Such microscopic defects, which are very difficult to prevent and to evaluate, especially on cast materials, may lead to incipient cracks under hard mechanical or thermal alternating load and, subsequently, early failure of the valve. The valve trims are compatible with the Ecotrol system, which offers easy maintenance with an exchangeable, clamped seat ring. That means there is no seat thread requiring special tools. Parabolic or perforated plugs are available in a wide range of rated flow coefficients. The valves are delivered with butt-weld ends per EN 12627 or ASME B16.25, with pipe outer diameters from 33.7 to 76.1 mm. Optionally, socket-weld end or threaded connections are available. — *ARCA Regler GmbH, Tönisvorst, Germany*
www.arca-valves.com

The launch of a new magnetic level-gage switch

The new LMS200 magnetically actuated level-gage switch (photo) is non-invasive and designed to improve the ease of use, safety and reliability of magnetically coupled switches in demanding conditions. The level setpoint is easily adjustable without changing any process piping or risking a plant shutdown. The gage is RoHS 2.0 compliant with global Hazloc ATEX/IECEx and cFMus approvals. When mounted on the company's KM26 magnetic liquid-level gage, or any other magnetic level gages that contain a magnetic float, the LMS200 switch can sense high or low levels within a vessel. The unique magnetic coupling action avoids the need for seals, diaphragms, springs or torque tubes. — *ABB Inc., Warminster, Pa.*
www.abb.com

A new mixing impeller for medium-viscous systems

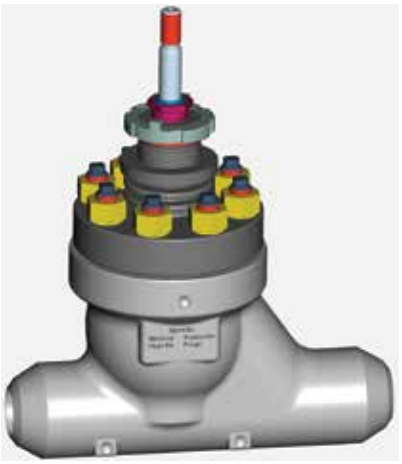
Multi-product reactors with enhanced heat-transfer requirements are often equipped with simple radially working mixing systems with various types of impellers. To improve the performance of such reactors, this company has developed the Varioblade (photo), which is a flexible, modular impeller with an optimized split between axial and radial flow components by different shapes of the upper and lower impeller parts. Compared to standard frame- or blade-type impellers, the blend times — especially in the mid-viscous range — can be improved by up to 50%, says the company. The Varioblade is not a close-wall-clearance system, but operates in the center of reactors, typically with coils, where radial flow components are required. The positioning of the three elements — outer blade, inner blade and bottom anchor — can be varied. Therefore, this impeller can handle different mixing-task combinations with varying viscosities up to 50,000 cP. — *Ekato Group, Schopfheim, Germany*
www.ekato.com

Pump impeller delivers improved suction characteristics

Movitec multistage high-pressure pumps (photo) feature a new impeller that significantly improves the pumps' suction characteristics, including net positive suction head (NPSH). The impeller is particularly suitable in applications with critical inlet conditions (for instance, boiler-feed applications), as well as applications in which the pump is required to take in water from low-lying tanks or at higher temperatures. Under these conditions, a pressure drop in the intake area may cause cavitation to occur in the first pump stage. This can result in excessive wear of pump parts or motor bearings, as well as a reduced service life of the pump due to damaged parts and an unbalanced hydraulic system. The new impeller is offered as an alternative to the standard product. The new impeller features a modified inlet diameter, vanes allowing a slightly diagonal throughflow and a newly designed stage casing, all of which serve to substantially improve the pump's NPSH curve. — *KSB SE & Co. KGaA, Frankenthal, Germany*
www.ksb.com

Gerald Ondrey

ARCA Regler



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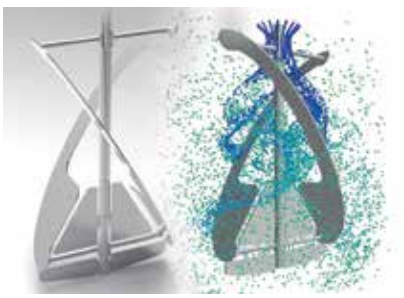

Ekato Group

KSB

Alfa Laval

Rembe

New disc technology boosts centrifuge separation capacity

UniDisc (photo) is this company's latest innovation for disc stack separators. This new disc technology is said to increase separation capacity by as much as 30%, while simultaneously providing an extremely high degree of hygiene. Unlike traditional separator discs with caulks that have been welded to the plates, discs with UniDisc technology feature micro-caulks that are formed during the pressing process. This ensures even, minimal spacing between the discs in the disc stack. By reducing the amount of spacing between each disc, it is possible to fit more discs within the same volume. Increasing the number of discs, in turn, means increased separation area with an improved flow capacity. The micro-caulks are integrated into the design of the disc itself. The multitude of small caulks strengthens the disc construction while simultaneously ensuring greater hygienic properties than possible in previous generations of disc stack technology. — *Alfa Laval AB, Lund, Sweden*

www.alfalaval.com

Aerzener Maschinenfabrik

High-pressure rupture discs now have extended service life

Since this company's engineers have modified the standard rupture-disc design, its high-pressure rupture discs (photo) have become significantly more durable. The welding seam of the rupture disc is not stressed as usual, in terms of shearing and bending, but only in terms of pressure. Through the geometric separation of the stress spike and the welding seam, the rupture disc is longer-lasting and allows the lowest rupture tolerances of up to ±3% at pressures of up to 5,000 bars and temperatures up to 400°C. — *Rembe GmbH Safety + Control, Brilon, Germany*

www.rembe.de

ecom instruments

This compressor is more compact than its predecessors

The new Aerzen Turbo G5^{plus} (photo) high-efficiency turbocompressor features air-foil bearings with a double coating of Teflon and graphite, which provides increased temperature resistance and a lifetime of more than 80,000 h of operation — independently from start and stop cycles. A new multilevel frequency converter technology (>55 kW) reduces the heat loss in the motor to a minimum and, consequently, improves the total efficiency significantly. Turbo G5^{plus} is offered for volume flows from 300 to 8,400 m^3/h, and for a maximum pressure of 1,000 bars. Eight blower sizes from the small AT 25-0.8 G5^{plus} to the largest model AT 200-1.0 G5^{plus} are currently available, and five more are in preparation. — *Aerzener Maschinenfabrik GmbH, Aerzen, Germany*

www.aerzen.com

A tablet that enables augmented reality applications

The newest product in the Tab-Ex series of hazardous-area mobile devices (photo) is based on the latest Samsung Galaxy Tab Active2 and integrates augmented reality (AR) applications. With the Tab-Ex 02, users can communicate in realtime, as well as collect and retrieve data, parameters and information remotely. Due to its magnetic gyroscope, the tablet enables users to identify objects in an installation via AR applications. The software delivers all underlying, existing data directly on the mobile device's display in realtime, while also making it shareable within a company's network. Whether through construction plans, maintenance information or operating states, the reality is enriched and extended by virtual data already stored in the plant. The mobile use of AR can solve multiple challenges and tasks in the industry, from rapid commissioning of a plant, transparent processes and precise maintenance to efficient asset management. — *ecom instruments GmbH, Assamstadt, Germany*

www.ecom-ex.com

Kilogram Standard

Department Editor: Scott Jenkins

The kilogram is the last of the SI units (International System of Units) still defined by a physical object, rather than defined in terms of universal fundamental constants of nature. However, this will change in November 2018, as a multi-year effort culminates in the adoption of a new definition for the kilogram that is based on Planck's constant. This one-page reference describes the effort to redefine the kilogram standard, shifting the definition from a physical object, which can change over time, and to a definition according to stable and reproducible constants of nature.

The kilogram is currently defined as the mass equal to a polished cylinder of platinum and iridium known as the International Prototype of the Kilogram (IPK; photo). Cast in 1879, it is currently housed at the Bureau International des Poids et Mesures (BIPM; Sèvres, France; www.bipm.org). According to the U.S. National Institute of Standards and Technology (NIST; Gaithersburg, Md.; www.nist.gov), "The accuracy of every measurement of mass or weight worldwide depends on how closely the reference masses used in those measurements can be linked to the mass of the IPK" [*1*].

Re-defining the kilogram

With improved measurement technologies, metrologists have shown that the masses of IPK and other reference artifacts have diverged by about 50 µg over the past 100 years. Even if stored carefully and used sparingly, physical objects can lose or gain atoms over time. Defining the kilogram based on natural constants would, in theory, allow the exact kilogram measure to be available globally and in a way that is stable over time.

Scientists have known for some time that the kilogram could be defined using Planck's constant (h), but techniques for measuring the constant were not able to generate the precision needed to allow a new definition to replace the physical kilogram standard.

Named for German physicist Max Planck, h is a proportionality constant between the minimum increment of energy for a photon, and the frequency of its associated electromagnetic wave. Planck's constant, a central component of quantum mechanics, allows researchers to relate mass to electromagnetic energy through mass-energy equivalence ($E = mc^2$).

Measuring Planck's constant

To measure Planck's constant with a sufficiently low degree of uncertainty, teams of scientists have been using two separate methods. The primary method involves a Kibble balance, an instrument designed for accurate measurements of h. Previously known as Watt balances, such instruments were renamed after the death in 2016 of their inventor, British metrologist Bryan Kibble. The other method involves counting the number of atoms in a silicon sphere to determine Avogadro's constant (N_A), which allows an alternate route to determine h.

According to NIST, a Kibble balance uses electromagnetic forces generated by a coil of wire between two permanent magnets to balance a mass [*2*]. The Kibble balance operates in two modes: first, electrical current is passed through the coil, which creates a magnetic field that interacts with the permanent magnets. This generates an upward force to balance the mass. In the second mode, the wire coil is lifted at constant velocity, inducing a voltage that is proportional to the magnetic field strength. With accurate measurements of current, voltage and velocity, enabled by the Kibble balance, Planck's constant can be calculated to a high degree of certainty, because it is proportional to the amount of electromagnetic energy needed to balance the mass.

BIPM

The new NIST measurement of Planck's constant is $6.626069934 \times 10^{-34}$ kg·m²/s, with an uncertainty of only 13 parts per billion (ppb). The agreement between the h values determined by the two methods (Kibble balance and Avogadro method) is very good, according to NIST scientists, with measurements differing by only a few parts per billion.

New definition

Work necessary to adopt the new kilogram definition is now in place, and the formal adoption will be announced at the 26th General Conference on Weights and Measures meeting in November 2018 [*3*].

Groups within the BIPM have been working on the adoption of the new definition and helping to integrate the new definition into familiar quality-control systems used by industry and science. Also, there will need to be an education campaign to explain these changes to user communities. ■

HISTORY

The history the kilogram standard can be traced to 1791, when, after a decree from King Louis XVI of France regarding the definition of length, the kilogram was defined as the weight of one cubic decimeter (based on the new length standard) of distilled water at its melting point. By 1799, French scientists of the time had fabricated a cylinder of platinum equal to that mass, and it became known as the kilogram of the archives (KA). A more detailed history of the kilogram can be found in Ref. 2.

In 1875, BIPM was established, as international teams of metrologists tried to come up with a successor to the KA. By 1880, metrologists had constructed a 90%-platinum, 10%-iridium mass that equaled the mass of KA according to the best measurement techniques of the time. It would become known as the IPK. Housed at the BIPM along with six official copies, the IPK has served as the definition of the mass of the kilogram since it was sanctioned in 1899.

References

1. Kilogram: Introduction, National Institute of Standards and Technology (NIST; Gaithersburg, Md.; www.nist.gov), Information on new kilogram standard, accessed August 2018.
2. Davis, Richard S. and others, A brief history of the unit of mass: continuity of successive definitions of the kilogram, *Metrologia*, 53, A12, 2016.
3. Bureau Internationale des Poids et Mesures (Sevres, France; www.bipm.org), information on redefining kilogram standard, accessed July 2018.
4. Abbott, Patrick, NIST, personal communications

Acetaldehyde Production from Acetylene

By Intratec Solutions

Acetaldehyde (also known as ethanal) is an industrially important, highly reactive aldehyde, mainly used as chemical intermediate in the production of acetic acid, peracetic acid and pyridine bases. Under certain conditions of acetylene price and availability, acetaldehyde can be made economically from that starting material.

The process

The following paragraphs describe a process for acetaldehyde production from acetylene (Figure 1).

Hydration. Fresh acetylene is mixed with recycled water and fed to an evaporator. The resulting vapor is mixed with fresh steam, heated and directed to hydration reactors. The reaction is conducted using four fixed-bed reactors, arranged in such a way that while three reactors are operating, one is in a catalyst-regeneration cycle by air injection (not shown in the diagram).

The preheated feed mixture is split, and part of it is introduced into the first reactor, where it contacts a bed of solid catalyst. The reaction mixture effluent, comprising acetaldehyde product, unreacted acetylene and steam, is withdrawn from the reactor, mixed with steam, quenched by water and fed to the second reactor, along with more fresh feed and steam. The reaction is carried out similarly in the second reactor and, subsequently, in the third reactor.

The effluent from the third reactor is cooled and routed to the crude product compressor.

Separation. The reactor effluent is cooled, partially condensed and fed to a separator, where a flash separation between gases and liquids occurs. The liquid stream from the flash separator (mostly heavy reaction by-products) is discarded. The gaseous stream, containing acetaldehyde and unreacted acetylene, is compressed in a multi-stage centrifugal compressor. The condensed water is recycled to the hydration reactors for use in quenching the reactor effluents.

The compressed gas is fed to the dehydration column, which further separates unreacted acetylene and acetaldehyde product from water. The column overhead — an acetaldehyde-rich stream plus acetylene — is directed to the acetaldehyde column.

A stream of essentially water is withdrawn from the bottom of the column and recycled, partly to the evaporator, and partly to the hydration reactors, for quenching reactor effluents.

Purification. In this column, a gas stream comprising unreacted acetylene is withdrawn from the overhead and mostly recycled to the hydration reactors. The remainder is discarded as offgas.

A stream of high-purity acetaldehyde product is withdrawn from the column bottom and directed to storage facilities located outside battery limits.

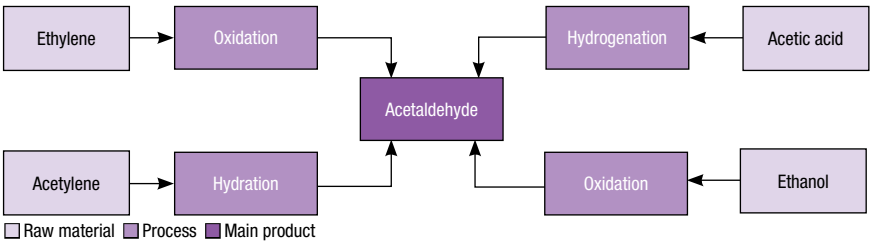

FIGURE 2. There are several production pathways for acetaldehyde

Production pathways

Acetaldehyde is produced at commercial scale mostly by liquid-phase oxidation of ethylene, and to a lesser extent, by the partial oxidation of ethanol and by the hydration of acetylene. Note that the route discussed here is economically feasible only under specific conditions of acetylene price and availability. Figure 2 presents different pathways for acetaldehyde production.

Economic performance

The total estimated operating cost (raw materials, utilities, fixed costs and depreciation costs) to produce acetaldehyde was about $1,640 per ton of acetaldehyde in the third quarter of 2014. The analysis was based on a plant constructed in the U.S. with capacity to produce 70,000 metric tons per year of acetaldehyde.

This column is based on "Acetaldehyde Production from Acetylene," a report published by Intratec. It can be found at: www.intratec.us/analysis/acetaldehyde-production-cost. ■

Edited by Scott Jenkins

Editor's note: The content for this column is supplied by Intratec Solutions LLC (Houston; www.intratec.us) and edited by *Chemical Engineering*. The analyses and models presented are prepared on the basis of publicly available and non-confidential information. The content represents the opinions of Intratec only. More information about the methodology for preparing analysis can be found, along with terms of use, at www.intratec.us/che.

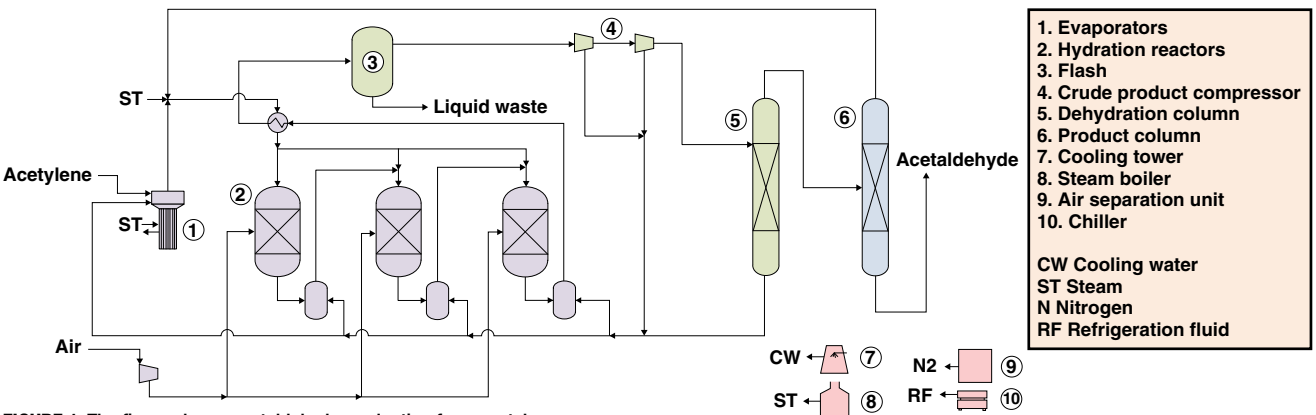

FIGURE 1. The figure shows acetaldehyde production from acetylene

Part 1

Treating Boiler Feedwater for Reliable Operation

These key elements of internal boiler feedwater (BFW) treatment will help avoid boiler tube failures due to scale and pitting

Dan Skiles
Cleaver-Brooks

IN BRIEF

BOILER FEEDWATER OPTIONS
DE-AERATION
OXYGEN SCAVENGING
TREATMENT FOR SCALE AND SOLIDS
PHOSPHATE TREATMENT
CHELANT TREATMENT
CONCLUDING REMARKS

For many chemical processes, an industrial packaged-type boiler is a critical component for either power generation or for producing steam. In the event that boilers are taken offline due to a failure, the facility may experience a loss of power or production downtime, each carrying significant economic consequences. Improper treatment of boiler feedwater can result in boiler tube failures due to oxygen pitting and scale buildup on internal heating surfaces. This article provides an overview of proper boiler feedwater treatment to help plants avoid failures.

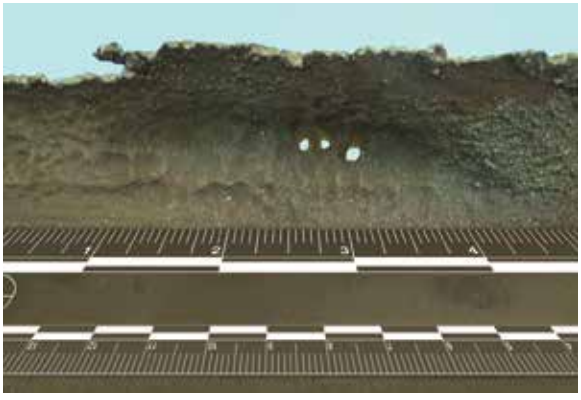

FIGURE 1. Pitting on the internal surface of a tube can result from the presence of oxygen in the boiler feedwater

Boiler feedwater treatment typically comprises a combination of several different processes, each designed to remove certain contaminants from raw make-up water or condensate return water. These processes can be divided into two parts: an upstream water-treatment system and a chemical treatment program. The upstream processes can include a combination of filtration, water softening, demineralization, reverse osmosis and de-aeration, depending on the quality of the raw water used. The chemical treatment program would include the introduction of chemicals to the boiler water to remove any remaining unwanted contaminants from the pressure vessel itself.

In this article, the primary focus is on the de-aeration process and the chemical treatment program.

Boiler feedwater options

For any commercial or industrial boiler-type application, the boiler feedwater can include raw make-up water, condensate return, or any combination of the two. Raw make-up water is defined as freshwater introduced into the system to account for losses in water or steam due to consumption by the process or from wastewater that is removed from the system. Condensate return water refers to water that has been condensed from the boiler steam after it has delivered heat to the process, and is then recycled back to the feedwater system.

For any application, the conservation of condensate return is ideal. Even though the condensate has lost some energy through the process, it is typically at a higher temperature (greater than 120°F, for example), and contains more energy than the raw make-up water (typically around 40–50°F). Note that regardless of how much condensate can be recovered, every application is going to require some make-up water due to losses throughout the system.

De-aeration

De-aeration is a critical feedwater treatment component for every boiler application. The raw make-up water fed from the upstream water-treatment system is saturated with

oxygen. Because the industry standard for boiler components and piping is to use carbon-steel materials, oxygen in the water will cause extensive corrosion to the components if it is not removed. Typical damage to any carbon-steel materials, including piping, boiler tubes and drums, will include pitting and thinning of the components due to the oxygen attacking the iron in the carbon steel (Figure 1). This pitting is a result of the basic reaction for the formation of rust (Equations (1) and (2)).

$$4Fe + 6H_2O + 3O_2 \rightarrow 4Fe(OH)_3 \quad \textbf{(1)}$$

$$2Fe(OH)_3 \rightarrow Fe_2O_3 + 3H_2O \quad \textbf{(2)}$$

These reactions remove material from the carbon-steel heating surface and can create deposits that can collect on the internal surfaces. These deposits reduce heat-transfer efficiency and can also plug the tubes, which creates potential hot spots that can lead to tube failures.

It may not seem that these reactions could pose such a threat to the boiler equipment. However, given that typical industrial packaged-type boilers can generate from 10,000 lb/h to more than 250,000 lb/h of steam, this type of flow would expose the boiler to a great deal of oxygenated water, and could result in corrosion and potential tube failures in a fairly short period of time.

FIGURE 2. Tray-type de-aerators are designed to remove oxygen from boiler feedwater to avoid corrosion issues

In order to remove oxygen from the water and mitigate the risk of corrosion, there are

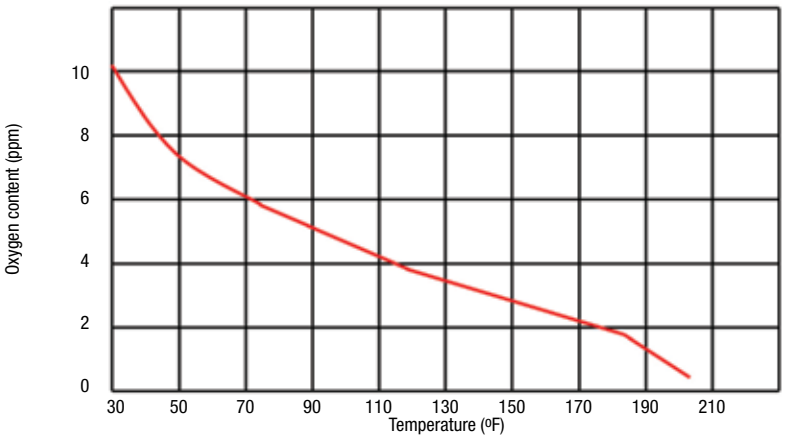

FIGURE 3. The relationship between oxygen content in the feedwater and temperature is shown here

two methods of de-aeration that can be used in combination with each other. The first is to use a piece of equipment that is referred to as a de-aerator, and the second is to use an oxygen scavenging chemical to remove any remaining oxygen from the system.

A de-aerator is used for virtually every boiler application at some stage during the feedwater treatment process. There are two designs that typically are used, a spray type and a tray type de-aerator (Figure 2), which, for the purposes of this discussion, provide essentially the same end result.

A de-aerator uses a combination of steam heating and turbulent mixing to remove the oxygen from the water to a level of 0.007 parts per million (ppm), as recommended by the American Society of Mechical Engineers (ASME) Water Quality Guidelines (Table 1). Note that the table shown here is abbreviated, and that the complete table includes recommended values all the way up to 2,000 psig.

In a tray-type de-aerator, the raw make-up water is sprayed into the top of the de-aerator column by means of a spring-operated sprayer or by spray nozzles. The spraying action generates small water droplets or a film, which flow downward between trays or deflection baffles. To avoid corrosion, the interior of the de-aerator includes stainless-steel materials for any wetted parts that come into contact with the oxygen-rich make-up water. The steam used to heat the water enters the de-aerator in the lower part of the tray section and rises through the sprayed water in a countercurrent-flow manner. As the steam and water mix, the incoming make-up water is heated from the typical inlet temperature of 40–50°F to the saturation temperature in the de-aerator, and the oxygen is driven out of the water as a result of the heating and mixing. The oxygen is allowed to vent to atmosphere from the top of the de-aerator. The steam is condensed into the make-up water as it transfers heat, and the mixture then flows downward into a feedwater storage tank. Note that the saturation temperature of the tank may vary depending on the specific operating pressure of the de-aerator. Typically, these are operated at pressures of 5–15 psig and temperatures of 228–250°F. The relationship between the oxygen saturation content in the water and the water temperature is demonstrated in Figure 3.

TABLE 1: ASME WATER QUALITY GUIDELINES

ASME Document No. CRTD (Vol. 34) "Consensus on Operating Practices for the Control of Feedwater & Boiler Water Chemistry in Modern Industrial Boilers"			
Drum operating pressure, psig	0–300	301–450	451–600
Feedwater			
Dissolved oxygen ppm (mg/L)			
O_2 measured before chemical oxygen scavenging	<0.007	<0.007	<0.007
Total iron ppm (mg/L) Fe	<0.1	<0.05	<0.03
Total hardness ppm (mg/L)*	<0.3	<0.3	<0.2
pH at 250°C	8.3–10.0	8.3–10.0	8.3–10.0
Boiler water			
Silica ppm (mg/L)	<150	<90	<40
Total alkalinity ppm (mg/L)*	<700	<600	<500
Total Dissolved Solids in Steam			
TDS (maximum) ppm	1.0–0.2	1.0–0.2	1.0
*as $CaCO_3$			

Oxygen scavenging

Even after the reduction in oxygen from the de-aerator, there is still a small amount of oxygen remaining in the feedwater, and this is enough to cause corrosion. In order to remove this residual oxygen, the de-aerator can be supplemented with an oxygen-scavenging chemical. The typical system includes carbon-steel materials for the feedwater storage tank, feedwater pumps, piping between the de-aerator and the boiler, and boiler pressure parts. All of these materials would be subject to corrosion if the remaining oxygen is not removed. Because all equipment downstream of the de-aerator is made from carbon steel, the oxygen scavenger should be introduced as far upstream as possible, in the feedwater storage tank that is directly connected to the de-aerator itself.

Three of the most common types of chemical treatment used for oxygen scavenging are sodium sulfite, hydrazine and carbohydrazide. Each of these chemicals provides different benefits that should be considered before selecting which oxygen scavenger should be used for a particular application.

Sodium sulfite. Sodium sulfite typically

comes as a powder or in an aqueous solution, and is generally the most economical chemical used for oxygen scavenging. The sulfite is very effective and reacts with the dissolved oxygen in the water according to the reaction shown in Equation (3), removing the oxygen from the system. With this chemical reaction, the sulfite attacks the oxygen at a ratio (dosage) of approximately 7.5 parts sulfite to 1 part oxygen.

$$2Na_2SO_3 + O_2 \rightarrow 2Na_2SO_4 \quad \textbf{(3)}$$

In this reaction, the sulfite and oxygen form a solid sodium sulfate product, which is carried through in the feedwater. The solid must be removed from the boiler water via the blowdown that is discharged from the boiler system as wastewater (Figure 4). Depending on the specific requirements of an application, this can be one of the drawbacks to using sodium sulfite — this end product adds to the overall solids concentration in the boiler water. With higher-pressure boilers, or boilers that are generating steam to drive turbines, maintaining a low solids content in the steam is more critical, and the use of a sulfite scavenger would not be recommended in those cases.

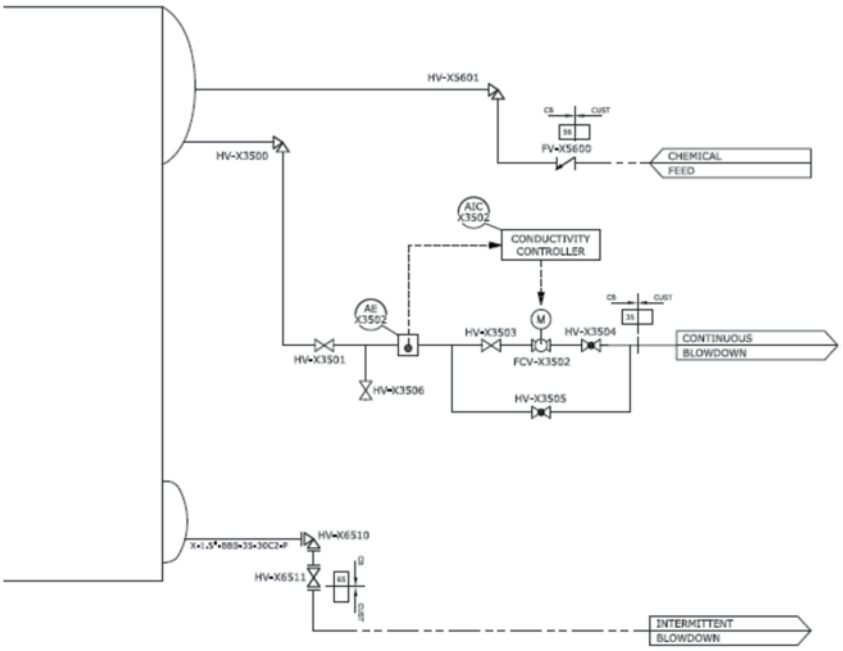

FIGURE 4. The diagram shows a typical boiler blowdown configuration

Another factor to note is that the sul-

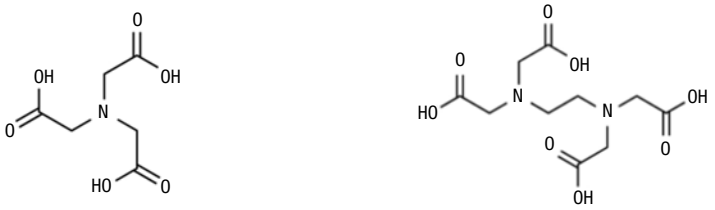

FIGURE 5. Molecules such as nitriloacetic acid (NTA; left) and ethylenediaminetetraacetic acid (EDTA; right) can chelate scale-causing minerals to prevent them from precipitating on heat-transfer surfaces

fite can break down and react with the water at lower pressures (less than or equal to 600 psig), forming sulfur dioxide and/or hydrogen sulfide. These two gases are carried through the system in the outlet steam, reducing the alkalinity of the steam and any condensate return. This low alkalinity causes acidic conditions downstream of the boiler, and can result in corrosion to the system.

One last item that should be considered regarding protection of the materials downstream of the boiler is that the sodium sulfite is nonvolatile, and would not be carried in the boiler steam throughout the system like the sulfur-containing gases would. Therefore, using sodium sulfite as an oxygen scavenger would not provide the benefit of protecting the materials downstream of the boiler, including any condensate that may be part of the boiler feed system.

Hydrazine. Hydrazine is the second option that may be used for oxygen scavenging. This chemical comes as a colorless liquid and also can be added directly to the feedwater storage tank upstream of the boiler. The hydrazine reacts with the remaining oxygen in the feedwater according to the reaction shown in Equation (4). The hydrazine attacks dissolved oxygen at a ratio of 1 part hydrazine to 1 part oxygen.

$$N_2H_4 + O_2 \rightarrow N_2 + 2H_2O \quad \textbf{(4)}$$

The products of the reaction are simply nitrogen and water, so this scavenger does not add any solids content to the boiler system and does not impact the boiler blowdown rate. This makes hydrazine a better choice for any applications where lower solids content in the steam must be maintained. Also, because the hydrazine does not create any corrosive gases that can be carried through, the alkalinity of the boiler system is not affected by the use of this chemical.

Something that must be considered when using hydrazine is that if the given application calls for steam that is greater than 750°F, the hydrazine will start to break down and form ammonia. Depending on the trim and valve selections for the boiler and low-pressure feedwater system, the presence of ammonia can cause potential issues. Ammonia will attack any "yellow metals," or metals containing copper. This possibility must be considered in the design of any new systems, as well as existing systems that may use these types of materials.

Carbohydrazide. The third oxygen-scavenging chemical to discuss here is carbohydrazide. The reaction between carbohydrazide and oxygen is shown in Equation (5). The reaction is ideal, as it can be achieved at fairly low pressures and temperatures as seen in a typical deaerator. Similar to hydrazine, the lower molecular weight of carbohydrazide makes it able to react at a ratio of 1.4 parts carbohydrazide to 1 part oxygen.

$$H_6N_4CO + 2O_2 \rightarrow CO_2 + 2N_2 + 3H_2O \quad \textbf{(5)}$$

This reaction also does not generate solids, so the boiler blowdown rate is not affected by this scavenger. One benefit that carbohydrazide offers, but hydrazine does not, is that it is volatile. Any carbohydrazide that is remaining in the water can be carried by the steam out of the boiler, which helps to protect any carbon-steel materials in the downstream system. It is important to be aware that this carbohydrazide can break down to hydrazine at higher temperatures (higher than 350°F). However, given the typical operating conditions of a de-aerator (228–250°F), this should not be an issue if injected directly into the feedwater storage tank, where it can react prior to being heated to above this 350ºF threshold in the boiler.

The three chemicals discussed here are considered to be among the most commonly used oxygen scavengers for industrial boiler systems. Each of the chemicals is capable of removing residual oxygen from the boiler feedwater, but should be evaluated based on its individual benefits. Beyond these three, there are also several other oxygen-scavenging chemicals used. It is recommended to coordinate the use of these chemicals with a local water-treatment or chemical provider based on the specific water quality in a given plant.

Treatment for scale and solids

In addition to de-aeration and oxygen scavenging, boiler feedwater typically requires additional chemical treatment for the removal of solids that are left in the water after going through the upstream treatment system. These solids can include silica, calcium and magnesium compounds, and vari-

ous others that contribute to the hardness of the water. Removing these solids helps to mitigate the risk of scaling and deposits collecting on the heat-transfer surfaces. Scale is formed when the water boils off of the heat-transfer surface and solids are left to precipitate out, sticking to the surface. In an industrial boiler, this scale would occur on the internal surfaces of the boiler tubes and drums. As the scale builds over time, deposits collect on the surfaces, causing fouling, which at a minimum, reduces heat-transfer efficiency. In extreme cases, the deposits can actually clog or plug the boiler tubes. This creates hot spots in the tubes due to a lack of circulation (water cooling), and may cause them to rupture. If a tube failure occurs, this is likely to require significant downtime and potentially costly tube-replacement work.

There are three primary chemicals that are used to treat water hardness. These typically include the use of a phosphate or a chelant in combination with a polymer. The appropriate combination of these would be project-specific, depending on specific water quality and the water-treatment philosophy and standards of the facility. The phosphate treatment reacts with the scale-causing minerals, such as calcium and magnesium salts, and precipitates the hardness out of the water, since the products are insoluble. Chelant treatment is slightly different — the products of the reactions form soluble structures that remain in the water and do not collect on the heat-transfer surfaces.

Both the phosphate and chelant treatments usually are supplemented with a polymer, which acts as a dispersant. The polymer prevents either the precipitated or soluble materials from collecting on surfaces and forming scale or buildup of deposits. The products of either of these treatments form a sludge that typically settles into the upper and lower drums of the boiler. Because the sludge has been conditioned by the addition of the polymer, it does not adhere to the surfaces and is removed via continuous or intermittent blowdown. The rate of blowdown required for removing this sludge can be set using manual valves, or can be monitored and modulated with the use of a conductivity controller.

Phosphate treatment

When using phosphates for water treatment, the precipitation of calcium and magnesium compounds are achieved through a number of reactions that can occur in combination with each other. These reactions are possible with the heating of the boiler water and the presence of calcium, sodium and magnesium. Several intermediate hydroxide and carbonate products can be formed due to the heating of the boiler water and the potential for carbon dioxide to be present. The reaction with the phosphate occurs when both calcium and magnesium are present as bicarbonates [Equations (6) and (7)].

$$3Ca(HCO_3)_2 + 2H_3PO_4 \rightarrow Ca_3(PO_4)_2 + 6H_2O + 6CO_2 \quad \textbf{(6)}$$

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \rightarrow Mg(OH)_2^{-} + 2CaCO_3^{-} + 2H_2O \quad \textbf{(7)}$$

For the calcium reaction, the desired end product is calcium phosphate, where the initial magnesium reaction forms a magnesium hydroxide. Both of these products will precipitate out of the boiler water and can be removed from the boiler with the blowdown. If silica is present, it is preferred that the magnesium hydroxide undergo a second reaction to form magnesium silicate. With this, both the magnesium and silica would be able to precipitate out of the boiler feedwater. One of the benefits of phosphate treatment is that it helps to maintain sufficient alkalinity for this reaction to take place. The phosphate treatment would be supplemented with a polymer to condition the solids to remain dispersed in the water until they settle to the bottom of the drum for removal with the blowdown.

Chelant treatment

A chelant is a molecule that is able to bind to a positively charged metal ion (cation). This type of chemical treatment involves the introduction of a fairly weak organic acid that is able to react with the calcium, magnesium and other metals in the water. Once this reaction has occurred, the resulting product is unable to deposit itself on the boiler heating surfaces because it is soluble in the water. Similar to the phosphate treatment, a supplemental polymer also would be added to act as a dispersant to allow the deposits to settle in the drum(s) for removal with the blowdown.

Two common chelants that are used for boiler feedwater treatment are nitrilotriacetic acid (NTA) and ethylenediaminetetraacetic acid (EDTA), shown in Figure 5.

Both of these are very effective at binding with the metals in the water, as they each contain multiple reaction sites. NTA contains four sites (1 N + 3 OH), and EDTA contains six sites (2 N + 4 OH). Both chemicals form a ring-like structure when they react with the metals, and react on a mole-to-mole basis [Equations (8) to (13)].

$$Ca^{+2} + NTA^{-3} \rightarrow CaNTA^{-} \quad \textbf{(8)}$$

$$Mg^{+2} + NTA^{-3} \rightarrow MgNTA^{-} \quad \textbf{(9)}$$

$$Fe^{+3} + NTA^{-3} \rightarrow FeNTA \quad \textbf{(10)}$$

$$Ca^{+2} + EDTA^{-4} \rightarrow CaEDTA^{-2} \quad \textbf{(11)}$$

$$Mg^{+2} + EDTA^{-4} \rightarrow MgEDTA^{-2} \quad \textbf{(12)}$$

$$Fe^{+3} + EDTA^{-4} \rightarrow FeEDTA^{-} \quad \textbf{(13)}$$

Note that with these two chemicals, the EDTA will form a more stable ring structure around the metal atoms, because it has the two additional reaction sites. The NTA only is able to react at four sites, which makes the product more vulnerable to additional reactions with other negatively charged ions.

Similar to the oxygen scavenging chemical treatments discussed, the combinations of phosphate-polymer and chelant-polymer chemicals discussed here are considered to be among the most commonly used. Again, it would be recommended to coordinate the use of any chemicals with a local water-treatment or chemical provider based on your plant's specific water quality.

Concluding remarks

The chemical treatment required for boiler feedwater in any facility is dependent on the specific water quality at the given site and may require additional treatment outside of what was identified here. Boiler feedwater at any facility should be analyzed chemically and compared to the ASME Water Quality Guidelines to determine which chemical treatment options may be necessary, and which would best comply with the facility's water treatment program and philosophy. ■

Edited by Scott Jenkins

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Microbial Control in Cooling Water

Three chlorine-based strategies for controlling microbial load in industrial cooling water are evaluated here

Lynne Monticello
Nalco Water, an Ecolab Company

IN BRIEF

CHLORINE-BASED BIOLOGICAL CONTROL
SPECIFIC CONSIDERATIONS
CONCLUDING REMARKS

Industrial cooling-water systems are critical to the success of many chemical process industries (CPI) operations. Proper operation of cooling-water systems supports the financial drivers of energy efficiency, asset preservation and water savings, while optimizing overall process performance. When maintained properly, industrial cooling-water systems help enable processes to run seamlessly. Selecting the appropriate water-treatment solution for an industrial cooling-water system is critical, and typically includes consideration of mechanical, operational and chemical components of the system (Figure 1).

FIGURE 1. Microbial control must be considered for cooling tower systems to maintain operational efficiency

Among the important aspects of cooling-water treatment is the control of microbes. Biological control in an industrial water system is important for maintaining optimal performance in three areas: scale prevention, corrosion inhibition and fouling control. Failure to effectively control microbes in cooling water can cause the system to suffer from diminished operational efficiency, premature equipment failure, deteriorated product quality and increased health-related risks associated with biological fouling.

Sources of microbial contamination in industrial water systems are numerous and may include, but are not limited to, airborne contamination, water make-up, process leaks and improperly cleaned equipment. These microorganisms can establish microbial communities on any wet or semi-wet surface of the water system. Additionally, biofilms formed by growing microbe communities have strong insulative properties, which drive up energy usage if not managed properly. It is therefore important that microbial biofilms and other fouling conditions be controlled or reduced to the greatest extent possible to minimize operational concerns and health-related risks associated with waterborne pathogens.

There are many biological control strategies available to the CPI today, including three chlorine-based oxidizing biocides: bleach (sodium hypochlorite; NaOCl), chlorine gas (Cl_2) and chlorine dioxide (ClO_2). Bleach is easily accessible and well accepted, and is used in most industries. Chlorine gas is common in ammonia and municipal water industries, while chlorine dioxide is often used in food-and-beverage, institutional and power industries. Important drivers in all these industries include safety, performance, water quality, compliance, convenience, reliability and sustainability. This article evaluates the three main chlorine-based biological control strategies for each of the seven drivers.

Chlorine-based biological control

The following paragraphs discuss bleach, chlorine gas and chlorine dioxide in the context of the seven drivers mentioned above.

Safety. A core tenet for major industrial operations is safety. The biological control strategy selected impacts safety in a variety of ways, including risk of exposure, environ-

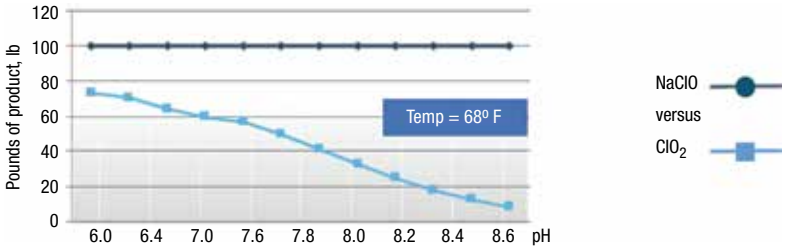


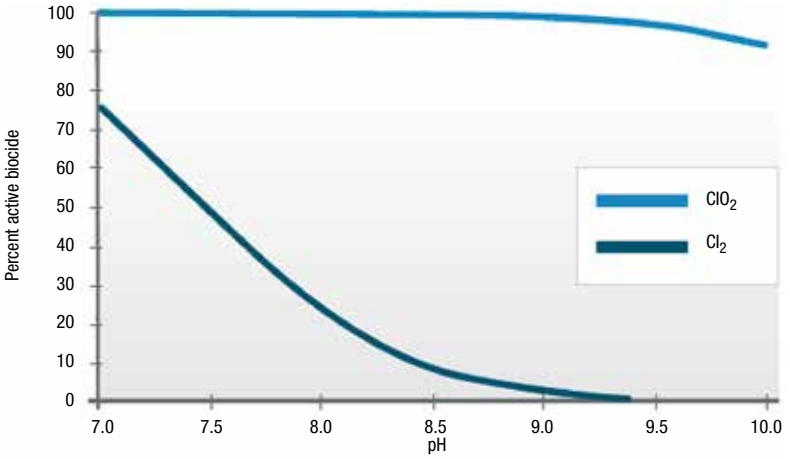
FIGURE 2. The graph shows the dosages of bleach and chlorine dioxide required to treat water at different pH levels

mental releases and sensitization of operators. Chlorine gas is highly toxic, making it a powerful disinfectant for water, but hazardous to humans, who must handle it in its gaseous form. As a result, operators require intense use of personal protective equipment for chlorine gas. For containment, chlorine gas requires high-pressure cylinders that come with an inherent risk of potentially large releases. It is important to note that safety and security legislation in many areas is expected to eventually force chlorine gas users to switch to a less hazardous program.

Utilizing bleach for microbial control requires a steady stream of bleach deliveries, each of which carries a risk of spills and worker exposure. Both bleach and chlorine gas add significant amounts of chloride ions to cooling water, increasing the risk of operator sensitization when exposed to cooling water.

In contrast, chlorine dioxide adds very little free chloride. For the same level of antimicrobial effectiveness, bleach requires a greater volume than chlorine dioxide. This may be a factor in reducing handling and exposure risks. Chlorine dioxide is generated on-site, as needed, so there is a need for a ClO_2-generation system, but no need for chlorine gas storage. This can be a factor in lowering the risk of a large-scale release. On-site generation equipment for chlorine dioxide requires integrated safety devices to monitor system parameters to ensure safe production of the chemical.

FIGURE 3. At pH levels greater than 7, chlorine gas is a less effective biocide, while chlorine dioxide maintains efficacy



Performance. After safety, process performance is the next key area for which the choice of microbial control program has an impact. In many cases, the three biocidal programs being compared for biocidal efficacy are dictated by system conditions and the particular requirements will determine the antimicrobial program. In low-demand systems with near-neutral pH, bleach and chlorine gas are effective biocides. Chlorine dioxide is especially effective in challenged water systems. Chlorine dioxide is well known to control and remove biofilms from industrial water systems as the compound migrates, via molecular diffusion, from the bulk water into the biofilm, where it deactivates microbes that form the biofilm.

In addition to microbial control, the impact of the water-treatment strategy on scale prevention, corrosion inhibition, and fouling reduction also must be considered. Bleach and chlorine gas both increase chloride and hypochlorite ions in the cooling water system. This can increase the rate of corrosion within the system, leading to shorter-than-expected asset lifetimes. Chlorine dioxide is not aggressive toward other cooling water chemicals that may be present in the system, such as azoles for corrosion inhibition and polymeric scale inhibitors.

Finally, due to the broad spectrum of chlorine activity, chlorine gas and bleach can create taste concerns, which can be especially troublesome in process applications in the food, beverage and healthcare industries.

Water quality. Incoming water quality is important to understand, because the pH range of the water system will determine the activity rate of the microbial control program. Bleach is most effective at a pH range of 5.5–7.5, and it tends to increase the pH of a system over time. When working with bleach, some operators will treat with acid to maintain the optimal pH range. This works, but also introduces additional hazardous chemistries (acid) into the plant. Chlorine dioxide is effective at a broader pH range (pH 5–11) and requires less intervention to maintain a consistent pH (Figures 2 and 3). The effects of pH are discussed further in the next section.

Compliance. Regulatory compliance is a strong consideration when determining the best path forward for microbial control. In the U.S., all biocides must be used in accordance with the U.S. Environmental Protection Agency and state environmental agency guidelines. Certain industries also have U.S.

Food and Drug Administration (FDA) and NSF International (Ann Arbor, Mich.; www.nsf.org) considerations to address. Discharge limits frequently regulate the amount of eco-toxic disinfection byproducts, such as trihalomethanes (THM), haloacetic acids (HAA), or adsorbable organic halides (AOX), that can be present in discharged water. The formation of these byproducts is significantly higher with bleach and chlorine gas than with the use of chlorine dioxide. In cases where the byproduct discharge limits are extremely tight, chlorine dioxide may be a strong candidate for microbial control.

Convenience. Ongoing maintenance is required for all biological control strategies. For chlorine gas, that means regular monitoring of the high-pressure system and hazard analysis on a routine basis. Bleach requires tank and line monitoring for impacts from corrosion. Chlorine dioxide requires regular maintenance of the on-site generation equipment. When selecting a program, consider the level of involvement that your staff is able to address. Preventive maintenance schedules that are managed by the supplier can provide assurance that technical experts have recently inspected the equipment and that it is in good working order. Operator training delivered by those same experts can ensure that as your workforce changes, knowledge of the cooling water system operation stays consistent.

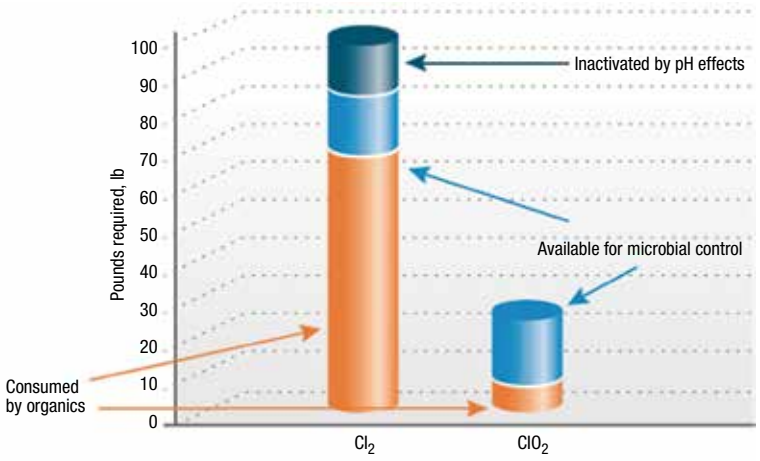


FIGURE 4. The effects of pH and contaminants present in the treated cooling water are different for chlorine gas versus chlorine dioxide

Another option that delivers convenience is remote 24-h per day, 7-d per week continuous digital monitoring of critical parameters with alerts to notify operators when the system requires attention.

Reliability. In today's world, the pressure to

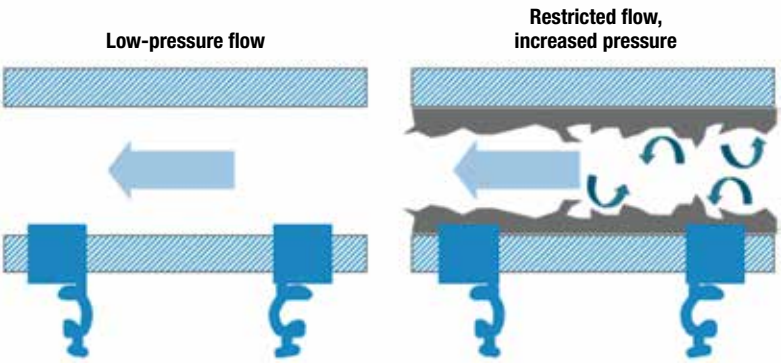


FIGURE 5. Slime buildup in the system can affect flow turbulence and pressure

do more with less falls on everyone's shoulders, so having a reliable solution and the additional expertise available to support process operations are more critical than ever. Bleach is a common microbial control chemistry and is effective with constant and consistent delivery. This requires a continuous supply of bleach moving around your facility to the appropriate application points. Bleach has a relatively short shelf life, especially under hot conditions, which adds to the need for frequent deliveries. Suppliers of bleach and chlorine gas tend to be commodity chemical suppliers who do not focus on unique situations or custom applications that arise frequently in cooling water systems.

On the other hand, chlorine dioxide requires on-site generation equipment that must be properly maintained to consistently and reliably deliver chemistry to water systems. Established chlorine dioxide suppliers have the expertise necessary to evaluate your application in order to survey, size and select the appropriate generation equipment for the needs of a particular process, and to apply the chemistry under the appropriate dosage scheme. The onsite generation of chlorine dioxide also enables the optimization of production throughput, as the system can accommodate fluctuations in production levels that may require variable production of chlorine dioxide.

Sustainability. All biocidal programs impact the sustainability of your operation. Energy-use and chemical-use cost savings are possible with bleach, but are greater with chlorine gas, and most significant with chlorine dioxide. This is mostly due to the reduction of biofilms, which greatly impact the efficiency of heat exchangers. In addition, there will be a decrease in energy consumption by cooling water pumps, as flow restrictions due to clogging are removed. Water savings are greatest for cooling water systems when the cycles of concentration can be maximized. Chlorine dioxide is superior for this driver due to the limited production of chloride ions.

Specific considerations

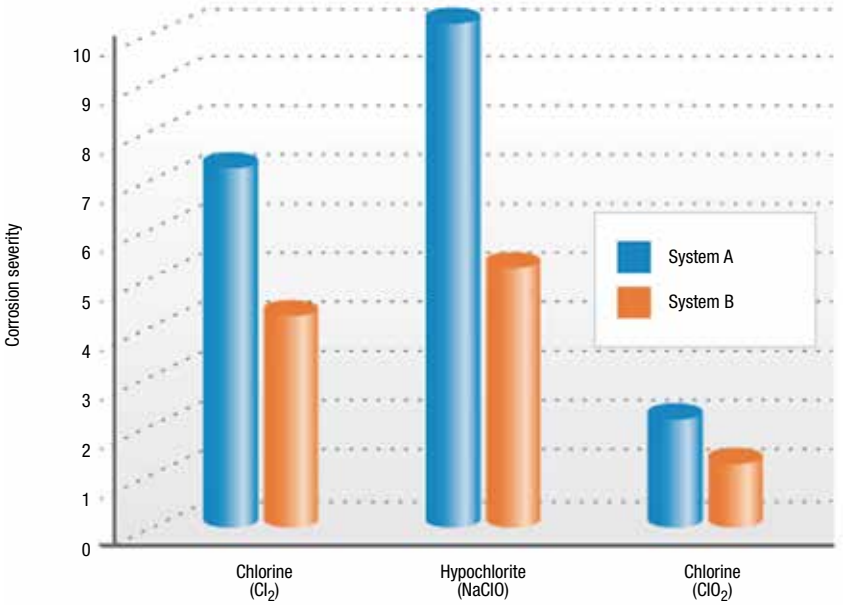
Assembled here are five additional considerations for use of chlorine-based microbial-control strategies in industrial cooling water applications.

pH. At a pH of 6.0–7.0, bleach has similar efficacy to chlorine dioxide, and is often used as a microbial control chemistry. Less chlorine dioxide is required to effectively reduce bacteria counts when compared to other chlorine-based programs at higher pH. Chlorine dioxide is effective across a broader pH range compared to chlorine gas and bleach. Figures 2 and 3 compare the equivalent dosage of ClO_2 per 100 pounds of NaOCl required to treat water at different pH ranges with the greatest benefit being seen at the upper end of the pH range.

Contaminant effects. Chlorine dioxide is less affected by pH and contaminants that create demand, such as oil, grease and ammonia. In addition to an overall lower rate of use, this means that the pH impact is minimized, thereby maximizing the microbial impact of the solution.

Figure 4 shows the effect of organic demand and pH on the free oxidant available for microbial control. The volume of bleach needed to maintain a similar level of free or available oxidant compared to

FIGURE 6. Corrosion rates and corrosion pit depths are different with the three chlorine-based biocides, as shown in the bar graph



chlorine dioxide, is much greater.

Impact of biofilms. As a dissolved gas, chlorine dioxide penetrates biofilm and removes slime. After the initial sloughing off of biofilm buildup in the system, this helps to restore heat transfer performance and energy efficiency. Figure 5 shows the impact of biofilm on flow, turbulence and pressure.

Corrosion. Corrosion rates affect the lifetimes of your assets. Corrosion rates and corrosion pit depth is reduced with chlorine dioxide. Figure 6 compares corrosion severity across two industrial water systems for chlorine gas, bleach and chlorine dioxide.

Concluding remarks

Biological control in an industrial water system is a key consideration in maintaining optimum performance. While there are many biological control strategies available in the marketplace, it is important to understand the differences between each and how they affect the drivers important to your site. Now that the key areas have been reviewed for chlorine-based treatments, you can evaluate each solution to determine which one best meets the drivers for your site. Safety, performance, water quality, compliance, convenience, reliability and sustainability are all important aspects of a robust solution and an optimal water-treatment program should also address mechanical, operational and chemical aspects of the system. ■

Edited by Scott Jenkins

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Protecting Sensor Data Transmitted Wirelessly: A Grounds-Up Approach

Do not assume security is extensive enough to protect your critical data and processes. Take a layered security approach using different tactics to establish best practices for protecting network data

Josh Schadel,
SignalFire Wireless Telemetry

Almost daily, the headlines tout the latest data breach that puts company proprietary information in jeopardy. To avoid such situations, many enterprises enforce different security measures to protect data from known and unknown risks. In addition to protecting information stored in the corporate infrastructure, businesses must also consider the data transmitted over any network. Attacks on wireless sensor and control networks can result in lost data and unintended system operations that cause production loss or safety issues.

Even information that seems to pose little risk if not secured can impact operations. A simple tank level reading may, by itself, seem unnecessary to protect. However, if an outsider tampers with data and changes the values, a false reading could shut down operations or even cause a spill. Therefore, both sensor readings and commands must remain valid. For example, a bogus "high" tank level alert sent by an attacker could trigger a production shutdown. Conversely, an erroneous "low" tank level warning could lead to tank overflow and spill.

As wireless sensing and control networks are more prominently used to monitor and control a wide range of assets in industries as diverse as oil and gas, agriculture, water treatment, food processing and transportation, network security is essential to ensure the authenticity, confidentiality and integrity of data as they pass from device to device. Using different security measures, companies can ensure data are only read by the intended recipient and remain valid without any content modification from the point of transmission to the point of reception. To validate sensor data passing through different transmission points, layers of protection must safeguard data packets from malicious attackers who could steal and change the contents. While wirelessly transmitting data without integrity checks is risky, many companies still do not implement security protocols to protect their network data.

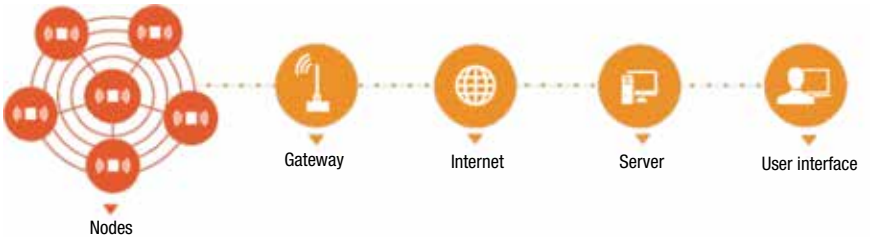

FIGURE 1. Security checks must protect sensor data as they passes through the wireless remote monitoring and control system. Using data without an integrity check is risky as it can cause unknown actions

Transmitting data wirelessly

Figure 1 outlines a standard configuration of a wireless asset monitoring-and-control system. Nodes extract, and transmit data from sensors via radio transmission to a gateway that serves as the central hub to serve data to a variety of applications. A wireless sensor network can concurrently monitor different assets from a variety of sensors in one network.

For example, in the upstream oil-and-gas market, measurements of level, temperature, vibration, pressure, flow and other parameters can be tied into one network. The gateway of such a network formats sensor data per industry standards (like Modbus) so that programmable logic controllers (PLCs), distributed control systems (DCS), supervisory control and data acquisition systems (SCADA) can process the data. The information is delivered and integrated over a wired digital protocol like Modbus serial (RS485), Modbus over Ethernet (Modbus TCP), Ethernet IP or wirelessly using cell modems or satellite communications.

More than automating data collection, these wireless telemetry systems are capable of managing assets "over the air" (sending an alert that controls a valve), eliminating the use of expensive cabling. Furthermore, the collected data are downloadable into analytics software for asset condition monitoring and predictive diagnostics.

One wireless sensor monitoring-and-control system can employ gateways that accommodate hundreds of transceiver nodes spread out over many square miles. Because of the wide geographic range of the network and critical nature of the processing facilities, security is a must to protect against potential breaches as data pass from point to point. The first line of defense is the sensor network as it packages the data. The second line of defense is the hub (that is, the gateway), where data are served to applications.

Types of data threats

Different types of data intrusions can interrupt a wireless sensor network or create some vulnerability, jeopardizing the reliability and integrity of information moving bi-directionally over the wireless network. A breach of the data moving to and from an asset could cause a problem with the plant or process operations. One common threat or technique to breach a digital

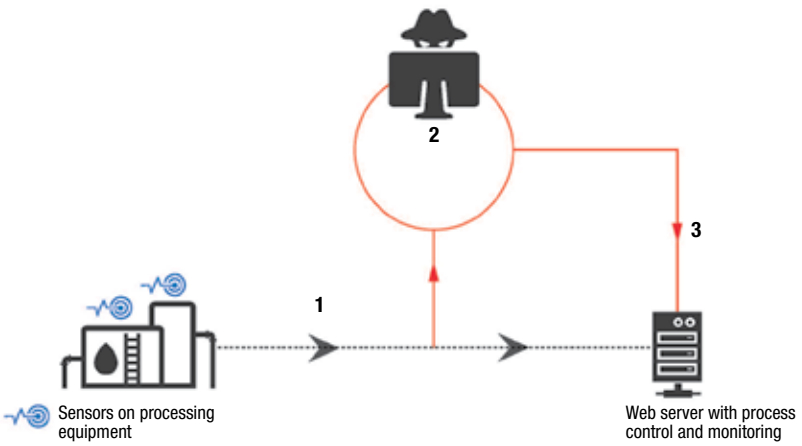

FIGURE 2. Shown here is an example of a replay attack, which can disrupt operations when messages are intercepted for delayed transmission

communication (wired or wireless) is a replay attack (Figure 2). For instance, a hacker could capture an encrypted message and retransmit it later to the network. This delayed/repeated message can cause potentially serious negative effects throughout the entire operation. For example, repeated transmissions of a low-pressure signal from a vessel could result in the control system not shutting a valve promptly to bring the process to a safe state.

Best practices

Companies employing wireless sensor networks, or any digital communication, should use a network security model (NSM) with multiple layers of security, such as encryption, device authentication and replay prevention. Here are some best practices to consider:

AES-128 data encryption. This type of encryption, by the U.S. National Institute of Standards and Technology (NIST), supports a more reliable and secure wireless network within all communication systems because it protects electronic data from intrusion and ensures only designated recipients can read the information. When implemented on low-power sensor devices, it protects against data tampering. The AES-128 works with a CBC-MAC algorithm on encrypted payload data that generates an authentication code sent along with data. If any data are modified, the authentication code becomes invalid as they will not correspond to the payload data. Therefore, the telemetry system will ignore the sent data packet. Only devices with the correct "key" will be able to decrypt the data.

Device authentication. Device authentication is a technique that ensures that nodes within a network pass an integrity check before joining a network. An encrypted, one-time-use token, along with address information, passes from a node to the joining network. The token is decrypted by the gateway (or other nodes already joined on the gateway) using the network key. If the node passes the integrity check and decryption, it will respond with a packet containing the token, address information, and network time. The use of the token stops a rogue network from attempting to absorb joining nodes and preventing them from communicating with their intended network. Additionally, this process allows only authenticated nodes to connect to the network.

Replay prevention. Replay prevention stops a malicious device from resending a message. A common security attack is the capture and re-transmission of a data packet. In replay attacks, the encryption is not broken but encrypted messages are captured and re-transmitted. For example, a message to turn on a relay could be captured and resent at a later time to disrupt operations. In a way, a replay breach can be described as a device analyzing a communication to determine the start and end of a transmission so it can then copy and paste the message *ad hoc*. Without replay prevention, this message could be resent without the receiving node knowing its delivery was from an attacker.

For example, should an encrypted message "to turn on a relay or change the state of an output" be captured and sent later, operations could be at risk. Replay prevention

FIGURE 3. Secure commercial systems use firmware, including data encryption and device authentication, on their wireless remote-monitoring products for a more reliable and secure wireless network infrastructure

schemes are typically based on time synchronization of all nodes in the network or message sequence numbers, allowing only fresh messages to be accepted by the network. Many wireless-encryption standards do not protect against this type of attack.

FHSS. Frequency Hopping Spread Spectrum (FHSS) protocol continually changes the radio frequency (RF) of transmissions and receptions to avoid RF interference. Frequency hopping systems typically use a minimum of 50 channels and hop in a random pattern to increase security, as an attacker must synchronize to the frequency channel to receive or transmit a message. If a message is sent on the wrong channel, the network will not receive it.

Who is responsible?

Protection for the wireless sensor network must extend beyond standard information technology (IT) security applied to computer networks and user interfaces. The first line of defense is a wireless technology capable and responsible for protecting its information. Companies must ensure the selection of wireless sensor monitoring and control solutions from vendors that offer multiple layers of protection and not just data encryption (Figure 3).

Data breaches can happen anywhere, even in remote locations unattended by operators for extended periods. Discuss security features with your vendor to ensure that security measures are extensive enough to protect your data network.

Concluding remarks

Users of wireless sensor networks should not overlook the risks of intruders tampering with data that control their production processes. Do not assume security is extensive enough to protect your critical data and processes. Take a layered security approach using different tactics to establish best practices. Consider the type of data and control messages that the wireless sensor network will transmit and evaluate the possible consequences of not properly securing that data. In almost all cases, data breaches or attacks put operations and processes at risk. Even in remote locations that are not readily accessible, threats can be present, often without companies realizing it until experiencing a problem. ■

Edited by Gerald Ondrey

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Gas Detection as a Risk Mitigation Technique

There are many differences between gas detection systems used for process monitoring and those used for protecting the safety of personnel

Jon D. Miller and Bill Crosley
Det-Tronics

Some types of gas detectors keep an eye on production processes. Others, relying on a number of different technologies, can help save lives. While both functions are important in a chemical processing plant, there are significant differences between gas detection equipment for monitoring the production process versus gas detection equipment for mitigating risk and maintaining life safety (Figure 1).

FIGURE 1. Gas detectors for process monitoring provide continuous measurements of gas concentrations in supply lines; they have no role in personnel safety

TYPES OF DETECTORS

The first and simpler type of gas detector is used for process monitoring only. These detectors are integrated into a gas supply line for the sole function of continuously measuring the concentrations of gases in the supply line for process adjustments. Gas concentration monitors are subject to fewer and less stringent standards than detectors intended for alarm notification purposes. In addition, gas concentration monitors usually have simple displays and do not offer "smart" capabilities, such as built-in highway addressable remote transducer (HART) protocol. The HART protocol is the global standard for sending and receiving digital information across analog wires between smart devices in a system.

The second and significantly more sophisticated type of gas detector is used in a facility's hazardous-area safety system. These detectors are responsible for detecting leaks of combustible or toxic gases for alarm notification purposes. Because the devices are installed in high-risk areas, they have to be product certified for hazardous locations, as well as performance certified for the specific attributes and functions required. While gas concentration monitors can also be found in hazardous areas, a fact that contributes to the confusion between detector types, they cannot serve a life-safety function regardless of where they are installed.

Life-safety gas systems require not only the ability to detect risk — for instance, leaking gas — but also the ability to mitigate risk through action. Mitigation techniques range from alarm notification and ventilation actuation to equipment shutdown and evacuation notification. The guidance and recommended practices for a life-safety gas-detection system are spelled out by the International Electrotechnical Commission (IEC; Geneva, Switzerland; www.iec.ch) in the standard IEC 60079-29-2, Explosive Atmospheres — Part 29-2: Gas detectors — Selection, installation, use and maintenance of detectors for flammable gases and oxygen.

If gas never leaks, then the potential for harm to people, equipment or processes is decreased. So even before choosing effective life-safety gas-detection systems, plant engineers can minimize incidents caused by gas leaks by designing tightly controlled processes. This is done by following good engineering practices, such as minimizing the number of flange connections where leaks could occur.

Matching capabilities with needs

Plant owners and operators first need to understand whether the area they are planning for needs gas detection for process monitoring or for risk mitigation and life safety (Figure 2). One major application area for risk mitigation is within hazardous-area classified locations, defined in Chapter 5 of the National Electrical Code (NEC), National Fire Protection Association (NFPA 70). Areas deemed Class I are those where flammable gases, flammable liquid-produced vapors or combustible liquid-produced vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.

Class I Division 1 is a location where combustible materials are routinely present in ignitable concentrations, while Class I Division 2 is a location in which the same materials are handled, processed or used, but in which the materials are normally

FIGURE 2. Hazardous areas in hydrocarbon processing plants are protected by life-safety gas detectors as part of a total risk-mitigation system.

confined and can escape only in the case of accident, breakdown or failure, or in the event of abnormal operation of ventilation equipment.

A gas detector intended for risk-mitigation and life-safety functionality must be Class I Division 1 hazardous-area certified in order to ensure explosion safety even in the unlikely event of containment failure. In addition, the risk-mitigation and life-safety gas detector must be performance certified in order to ensure proper safety actions are taken to mitigate the situation.

However, a gas-monitoring detector can be Class I Division 2 hazardous-area certified to monitor a contained process if the area is classified as Class I Division 2 and no performance certification is necessary, due to its non-safety purpose. It is important to note that maintenance of these gas-monitoring devices requires physical access, which requires decommissioning an area and can in turn result in costly plant downtime. To avoid process interruptions, some facilities instead elect to use devices appropriate for Class I Division 1, choosing higher capabilities and lower lifecycle costs over lower initial cost.

Setting the safety integrity level

Another consideration for understanding gas-detection requirements is the target safety integrity level (SIL) necessary for a facility. The SIL is a statistical representation of the integrity of the safety instrumented system (SIS) when a process demand occurs. Stated another way, The SIL helps quantify functional safety, which is the part of overall safety that depends on a system or equipment operating correctly in response to its inputs. The purpose of the SIS is to reduce risk, so SIL levels can be defined in terms of the risk reduction factor (RRF). The inverse of the RRF is the probability of failure on demand (PFD).

IEC 61508, Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems (E/E/PES), defines the requirements for ensuring that systems are designed, implemented, operated and maintained to provide the required SIL. Four SILs are defined according to the risks involved in the system application, with SIL 4 being used to protect against the highest risks. The standard also calls for a process that can be followed by all links in the supply chain so that information about the system can be communicated using common terminology and system parameters (Figure 3).

The specific SIL characterizes the requirements that must be met in order to achieve an overall risk reduction target. A risk assessment effort yields a target SIL that becomes a requirement for the final system. The requirements of IEC 61508 standards establish necessary con-

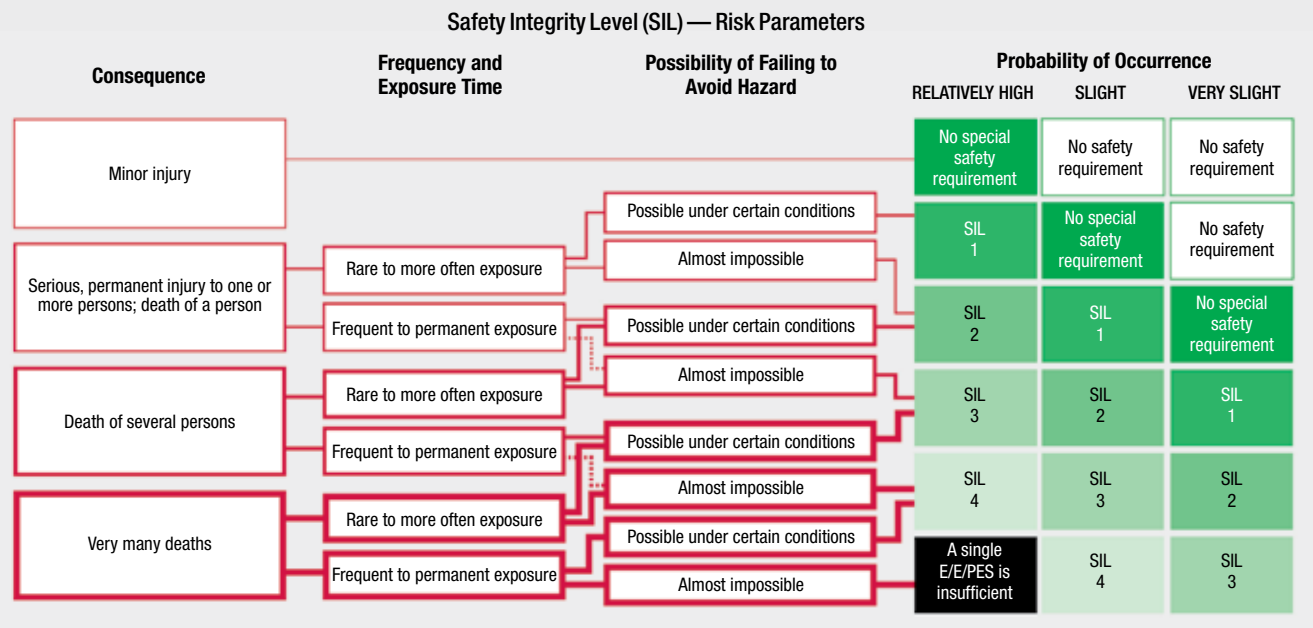

FIGURE 3. Safety integrity level (SIL) is defined as a relative level of risk-reduction provided by a safety function; a SIL (1, 2, 3 or 4) can be specified as a facility's target level of risk reduction. SIL is a measurement of performance required for a safety instrumented function (SIF), as defined in IEC 61508

straints of a product development process — including appropriate quality control, process management and verification and validation methodologies, as well as failure modes, effects and diagnostic analysis — so that one can reasonably justify that the final system attains the required SIL.

Further guidance related to SIL is provided by IEC 61511, Functional safety — Safety instrumented systems for the process industry sector. According to this standard, facilities must follow these guidelines:

1. Conduct a hazardous operation analysis and risk assessment to identify and evaluate problems that may represent risks to personnel or equipment. This evaluation will help in determining the facility's target SIL.
2. Develop auditing, verification and validation activities to improve the integrity of the safety-related functions.
3. Develop post-incident and post-accident activities for root-cause analysis and corrective actions.

In the case of SIL product testing, third-party organizations document the design of the process and test both hardware and software in order to provide a more complete evaluation of product operation. Compared to their non-SIL counterparts, products that have achieved third-party SIL certification generally offer improved diagnostics (by providing information on failure modes) and are likely to cut maintenance costs by reducing the frequency of calibration and testing.

Categories of risk

Given that the purpose of a hazardous-area gas-safety system is risk mitigation, it is appropriate to review the risks associated with combus-

Risk mitigation objectives: Gas detection type required				
	Risk-mitigation and life-safety gas detection		Process-monitoring gas detection	
Objectives	Combustible gas	Toxic gas		Notes
Priority #1: Explosion prevention	✓			1. Gas detectors for risk mitigation can also be used for validation of area classification (for example, less than 10 h flammable atmosphere exposure per year)
Priority #2: Personnel protection	✓	✓		1. Limits for short- and longterm exposure to toxic gas have been set by agencies, such as the U.S. Occupational Safety and Health Administration and Control of Substances Hazardous to Health in the U.K.
Priority #3: Equipment protection	✓			1. A gas-related equipment explosion will likely also pose a threat to people
Priority #4: Process protection	✓	✓	✓	1. Gas detectors for risk mitigation and life safety are needed outside of gas-carrying pipes to detect leaks that could pose a threat to personnel, equipment or facility 2. Gas detectors for process monitoring are needed to maintain production control

FIGURE 4. Risks related to toxic and combustible gases can be prioritized to help determine the appropriate type of gas detection required

tible and toxic gases.

Combustible gases are those that can cause a fire or explosion if the gas is exposed to an ignition source, such as a spark, a hot surface, an open flame or even friction caused by gas escaping through a pipe fissure. Containment is the first safety measure in relation to combustible gases, but the detection of leaks is a second critical safety measure. Many gases are both combustible and toxic.

A toxic gas is one that can cause harm to humans, ranging from minor irritation to death. Even at low concentrations measured in parts per million (ppm), certain toxic gases can cause death by poisoning caused by exposure to carbon dioxide or by asphyxiation. Asphyxiation occurs with exposure to atmospheres containing less than the concentration of oxygen needed for human life. The addition of any gas, except oxygen, to air reduces the oxygen concentration through displacement and dilution, particularly when the added gases are nitrogen or other inert gases such as argon and helium. Breathing as little as one or two breaths of air containing too little oxygen can have immediate and lasting effects, from unconsciousness to serious injury or death.

From a risk-mitigation perspective, there is a hierarchy of risk that should be considered when designing a plant's hazardous-area gas detection system. The risk mitigation objectives in Figure 4 are ranked in priority order, based on severity of risk. The type or types of gas detection required for detecting the risk underlying each objective are also listed.

Gas detection for risk mitigation

According to IEC 60079-29 Series standards and IEC 62990 Series standards currently under develop-

GAS DETECTION GUIDANCE DOCUMENTS (IEC, E.U., U.S. AND CANADA)

Combustible Gas Performance Standards

- IEC/EN 60079-29-1 Explosive Atmospheres — Part 29-1: Gas Detectors — Performance Requirements of Detectors for Flammable Gases
- CSA C22.2 No. 152: Combustible Gas Detection Instruments
- ANSI/ISA-60079-29-1 Explosive Atmospheres — Part 29-1: Gas Detectors — Performance Requirements of Detectors for Flammable gases; ANSI/UL 2075, Gas and Vapor Detectors and Sensors

Recommended Practice Standards:

- IEC/EN 60079-29-2 Explosive Atmospheres — Part 29-2: Gas Detectors — Selection, Installation, Use and Maintenance of Detectors for Flammable Gases and Oxygen
- C22.1 Appendix H: Combustible Gas Detection Instruments for Use in Class I Hazardous Locations
- ANSI/ISA-60079-29-2 Explosive Atmospheres — Part 29-2: Gas Detectors — Selection, Installation, Use and Maintenance of Detectors for Flammable Gases and Oxygen

Method of Protection Guidance Standards

- EN 1127-1 Explosive Atmospheres — Explosion Prevention and Protection — Part 1: Basic Concepts and Methodology
- C22.1 Appendix H (of the Canadian Electrical Code) Combustible Gas Detection Instruments for Use in Class I Hazardous Locations
- ANSI/ISA-TR12.13.03-2009: Guide for Combustible Gas Detection as a Method of Protection
- Other regional and local protection guidance standards

Notes

1. Though some regulatory authorities have laid out gas-detection system design and performance requirements, there are no documented rules concerning optimum detector placement or quantity. Hazardous operation analysis, however, can assist planners in this regard. So can past experience, which shows that it is helpful to identify the most likely sequence of events leading to a gas leak, as well as typical environmental conditions during leakages, when determining optimal sensor installation points.
2. The documents list above does not include all standards that may be applicable for a specific application or geographic location. ❑

ment, a life-safety gas system does more than detect the presence of combustible and toxic gases. It must be able to provide alarm notification if data from the detectors hit a certain threshold. It must also have the ability to take corrective actions, such as opening a vent, closing a valve or door or shutting down equipment to mitigate risk (Figure 5).

In life-safety systems, the detectors tend to have more feature-rich displays than gas concentration monitors, as well as smart capabilities that improve digital information transfers. The detectors are connected to a controller and various other devices that can take a number of different actions in order to help bring a dangerous situation back to a safe state.

In addition to detectors, a risk-mitigation gas system includes a safety system controller (SSC), which receives and interprets input from multiple detectors and decides whether or not some action needs to be taken. In order to prevent nuisance alarms, the SSC may discount information from a single detector if it is not confirmed by data from other detectors in the same area.

In descriptions of risk-mitigation or life-safety gas systems, the term "functional safety" can cause confusion. Not interchangeable with "life safety," functional safety relates to the evaluation of risk based on an assessment of the entire safety system. If a life-safety gas system has faulty wiring, for example, the risk level in terms of functional safety is higher even if the detectors and other devices in the system are in good working order.

Standards and certifications

Before embarking on the design of a life-safety gas detection system, plant engineers should also review applicable safety standards, which can provide the backbone of a plan to help ensure continuous safe operation of plant processes. Standards address which devices and systems should be included in a life-safety plan. There are also standards that deal with detector performance, installation, calibration and maintenance — all of which are critical to effective gas detection. See the box on p. 50, Gas Detection Guidance Documents, for further details.

Hazardous-location standards. These standards are meant to ensure that a device can survive and perform adequately in a hazardous-classified environment. These standards vary depending on the region of the world. The IEC sets standards followed as a basis by most countries, but in some cases, national deviations may apply. In the U.S., a major source of industry standards is the National Fire Protection Association (NFPA; Quincy, Mass.; www.nfpa.org). Since the 2010 Edition, NFPA 72 (National Fire Alarm and Signaling Code) has included gas detector criteria. NFPA 70 (National Electrical Code) also addresses the use of gas detectors as a method of protection.

Other key standards that apply to gas detection in hazardous

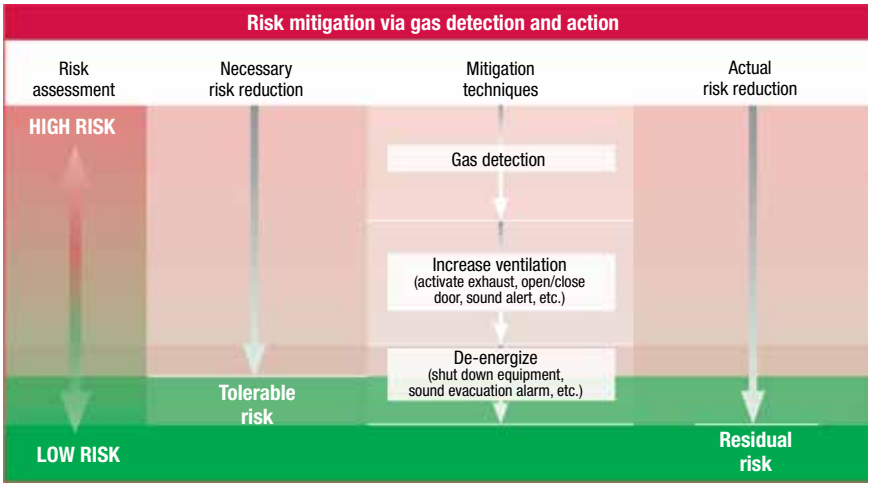

FIGURE 5. The gas detection system can perform a sequence of mitigation actions to reduce the risk level below the tolerable risk threshold. The strength of the mitigation actions taken increases with the severity of the ignition risk. Subject to conditions, the mitigation actions may or may not sufficiently reduce risk, so this process continues in a loop, continually monitoring and mitigating risk

areas include the following:

- Combustible gas; IEC 60079-29 Series; EN 60079-29 Series; UL 60079-29 Series; and CSA C22.2 No. 60079-29 Series from the Canadian Standards Association
- Toxic gas: IEC 62990 Series under development; European standard EN 45544 Series; and ANSI /ISA -92.00.01 from the American National Standards Institute (ANSI) and the Instrumentation Society of America (ISA)

Some standards set out the performance levels to which each life-safety device should be tested. Performance testing and certification verifies that a device will operate as specified by the manufacturer under worst-case standardized conditions. Some gas detector manufacturers self-certify product performance, meaning that they rely solely on their own internal tests and evaluations to attest that their products meet applicable standards. Others add to their own testing and evaluation a third-party testing organization's report, which may not be obtained through proper laboratory accreditation means. Though safety-device manufacturers know their devices and are knowledgeable in their field, properly accredited third-party testing and certification provides an independent and unbiased evaluation of the design and product performance. Furthermore, at any time, standards are being evaluated for relevant updates and potential new standards and recommendations are being developed. See the box on p. 54, Current Standards Activity, for a selection of in-development standards relevant to gas-detection technologies.

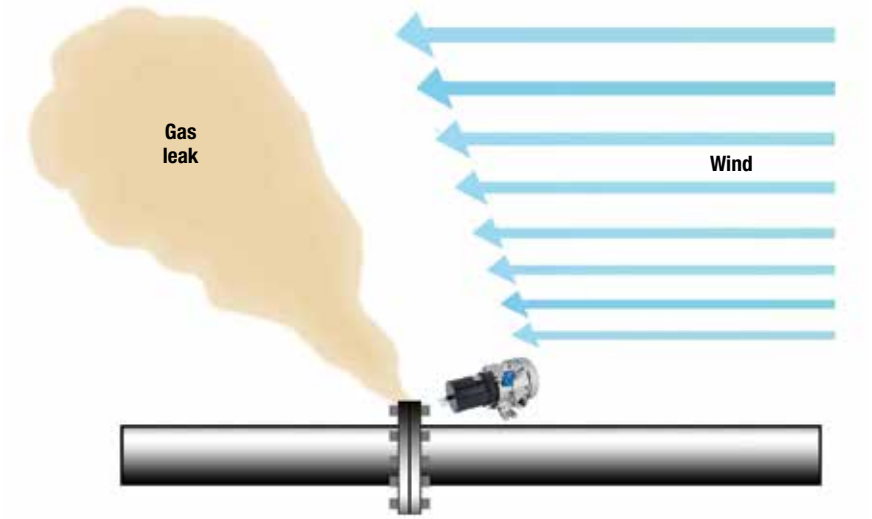

FIGURE 6. Point gas detectors monitor a specific area or point in a facility. Because the gas leak must come into contact with a point-type detector, performance of point detectors can be limited by environmental and application factors, as shown

Accredited third-party testing. Experts in reliability engineering and in certification process conduct accredited third-party testing activities. A number of independent organizations now have documented safety and performance criteria for gas detectors. These include Factory Mutual (FM) and Underwriters Laboratories (UL) in the U.S., the Canadian Standards Association (CSA), Det Norske Veritas — Germanischer Lloyd (DNV GL) in Norway and Germany and UL-DEMKO in Denmark. When these organizations certify a product, it means that independent experts have determined that it is fit for duty.

Process-monitoring gas detection systems can be self-certified by the manufacturer. In most regions of the world, however, life-safety gas detectors designed for hazardous locations must be performance-certified by an accredited third-party agency to the performance standards applicable in that location.

In the U.S., confusion is caused by the fact that one major certification organization, UL, puts gas detectors into two different certification categories, "Listed" and "Classified," rather than mandating clarity of use within the product manual. Listed means that the gas detector has been evaluated and approved for both hazardous locations and performance (for risk-mitigation and life-safety gas detectors). Classified means that the gas detector has been evaluated only for hazardous locations and that no performance evaluation has been done (for process monitor gas detectors). The bottom line is that UL Listed and FM approved gas detectors will meet the requirements of any gas detection application, while UL Classified gas detectors are suitable only for process monitoring.

In addition to detector performance in a life-safety gas system, the performance of the control architecture should be third-party certified from detection to action to validate the entire safety function relied upon. The SSC itself should also be properly rated for a hazardous classified location.

CHOOSING A DETECTOR

There are a number of different gas-detection technologies cur-

rently available. In order to choose from among them, plant personnel should consider the capabilities, advantages and disadvantages of each technology and compare these to the characteristics and requirements of the application.

The technologies discussed in this article are incorporated into what are known as fixed-detection devices, which are permanently placed in a location where gas leaks might occur. Fixed-detection devices are part of systems that protect people in a given area from harm caused by toxic and combustible gases. Besides performing their basic functions, advanced versions of fixed-detection instruments and systems offer onboard digital intelligence that allows diagnostic functions, historical data logging, digital communications and additional microprocessor-based functionality. The following sections detail the main types of fixed-detection devices offered by manufacturers of gas-detection devices.

Point gas detectors

Point-type gas detectors monitor a specific area or point in a facility. These detectors are used to indicate the presence of combustible or toxic gas. The gas must come into contact with the detector for sensing to occur. Point detectors require calibration for the gas type to be detected and must be regularly inspected to ensure that they are capable of performing as expected. Point detectors that are SIL 2 capable have maintenance procedures defined in their safety manual and may, in some cases, only require an annual bump test rather than quarterly inspection. (Figure 6.)

Catalytic. The small catalytic gas sensor (CGS) is the one most frequently installed to detect combustible gas. Operation of a CGS detector is based on heat created by the catalyzed reaction between oxygen in the air and a combustible gas. A CGS detector must be in the gas cloud for detection to occur.

Of all available gas sensors, CGS offers the greatest range in detection of combustible vapors. Those detected include hydrocarbons, hydrogen and acetylene. Catalytic sensors also offer good repeatability and accuracy, as well as fast response time and low initial cost.

However, a rapid increase of high-concentration combustible gas in an environment can quickly move ambient air out of the sensor so that there is insufficient oxygen to maintain the catalyzing process. In addition, catalytic sensors fail without signaling plant personnel, so they require routine bump testing and calibration, typically every three months. Catalytic sensors are also susceptible to poisoning from a variety of substances, including silicones, halogens, acid, vapors from polyvinyl chloride (PVC) and other corrosive materials.

Infrared. IR point-gas detection is based on the principle that hydrocarbon combustible gases absorb specific wavelengths of IR light. Detectors using this technology include an IR light source and a sensor to measure light intensity at IR wavelengths.

FIGURE 7. Line-of-sight gas detectors continuously monitor combustible hydrocarbon gas levels between two points at ranges of up to 120 meters. This allows a large coverage area, with the result that fewer detectors may be needed. However, a limitation of this technology is that is it unable to pinpoint the location of the leak

If gas is present in the optical path, the IR light intensity is reduced. This change provides the data needed to calculate gas concentration.

Like CGS detectors, IR detectors must be in the gas cloud for detection to occur. But unlike their CGS counterparts, IR sensors can only detect hydrocarbon gases, making IR detectors not suited for settings where there is danger from non-hydrocarbon gases, such as hydrogen, carbon disulfide and others.

Nevertheless, use of IR gas detectors is growing rapidly because they compare favorably to CGS detectors in other ways. For example, IR detectors are immune to contaminant poisoning, require less maintenance than catalytic sensors and are unaffected by changes in oxygen level or high gas concentrations. And unlike catalytic sensors, some IR detectors are failsafe, meaning that the instrument checks itself and reports any internal condition preventing detection.

In addition to combustible gases, point-type gas detectors are also designed to pick up leaks of toxic gases, such as hydrogen sulfide, carbon monoxide, nitrogen dioxide, ammonia, chlorine and sulfur dioxide. The detectors measure gas concentration at the point where the detector is located and give readings in parts per million (ppm). Contact with the gas is required for detection to occur.

Point toxic-gas detectors are placed where there is a potential for a toxic gas leak. Placement considerations include airflow in the area, as well as factors like the density and anticipated source of the toxic gas.

Electrochemical cells. For toxic gases, the most common fixed-detector technologies are electrochemical (EC) cells and metal-oxide semiconductor (MOS) sensors. EC sensors consist of electrodes connected via a load resistor. The electrodes are encased in a permeable membrane that diffuses detected gas across the electrodes. Once this occurs, the assembly is submerged in an electrolyte solution.

Available in a variety of different sizes and packages, EC sensors are used to detect a wide range of toxic gases in many applications. Generally considered the main choice for toxic gas detection, these sensors offer a number of advantages, including stability, repeatability, consistency, high sensitivity and low power requirements. On the downside, use of EC sensors is restricted in very hot and very cold environments. In addition, EC sensors are generally not failsafe, so in most cases they must be routinely inspected and calibrated to ensure proper operation.

Metal oxide semiconductor (MOS). There are many variations of the MOS technology, which is most frequently used if the target gas is hydrogen sulfide. MOS sensor advantages include long life, wide operating temperature range and excellent performance in low-humidity environments.

FIGURE 8. Acoustic gas detectors are non-contact leak detectors that recognize unique sound "fingerprints." They are ideal for locations where there is a risk of a high-pressurized gas leak

Open path or line-of-sight

Open path, or line-of-sight (LOS), gas detectors continuously monitor combustible hydrocarbon gas levels between two points at ranges of up to, or in some cases, greater than 120 meters. This detection technology uses a beam of light that travels between two modules. When a gas cloud passes through the beam, the gas concentration is measured. To ensure that the target gas passes through the beam, the modules must be strategically located and properly aligned. The modules themselves, however, need not be in the gas cloud for detection to occur (Figure 7).

As with point-type detectors, it is best practice that LOS detectors are calibrated for the gas type to be detected. Typically, open-path detectors are self-monitoring and will alert users in the case of a blocked light beam or some other trouble that adversely affects their operation.

LOS detectors should be designed to withstand harsh industrial conditions, including chemical exposure and heavy vibration. Other specific product features to look for include large-area coverage, failsafe operation, infrequent calibration requirements and low maintenance.

Disadvantages of the technology can include initial cost and the module alignment challenges that can prevent the detectors from working properly. Ideally, the design of the chosen detector will provide the largest possible field of view, which increases the modules' alignment tolerance, making installation faster and easier. In addition, LOS detectors do not provide a direct gas-concentration measurement, measured in

CURRENT STANDARDS ACTIVITY

Each part of the world has industry safety standards that address its specific needs as determined by local regulatory agencies. Gas detection standards, in particular, are evolving with the goals of providing more specific guidance and greater harmonization across standards and worldwide. Below are just a few of the topics being actively addressed today:

- ***Gas detection as a method of protection.*** The UL STP 9200 committee (chaired by article author Jon Miller) is working on UL 12.13.03, which is the second edition of ANSI/ISA-12.13.03 (but transition to UL)
- ***Gas detection for classified area monitoring.*** Requirements have been recently clarified in CSA C22.1:2018 (Canadian Electrical Code), and efforts are ongoing to revise the National Electrical Code with corresponding text to harmonize the two standards
- ***Personnel protection via toxic gas detector performance standards.*** The IEC TC31 MT60079-29 and JWG45 committees (IEC committees chaired by article author Jon Miller) are developing a Toxic Gas Detection Performance standard, Toxic Gas Detection Recommended Practice standard and Oxygen Gas Detection Performance standard ❑

percentage of lower flammable level (LFL); rather, the detector provides a gas-concentration measurement integrated over the entire beam length, measured in LFL-meters. Therefore, the detector cannot discern between a small, dense gas cloud and a large, dispersed gas cloud.

Intended to supplement rather than replace point detection systems, LOS detectors often work with point detectors to provide optimal protection of chemical facilities. In situations like this, the point detectors should be installed at or near known high-risk gas leakage points or accumulation areas to provide specific information about the level of gas present in these locations. As for the LOS detectors, they should be installed at plant or process-area boundaries, where they can monitor the plant perimeter and track gas cloud movement into and out of the facility. Movement of gas clouds throughout the facility can be followed by monitoring the output signals of all the gas detectors on a workstation graphic display screen.

Acoustic

Capable of recognizing unique acoustic "fingerprints," ultrasonic gas-leak detectors sense the high-frequency sound emitted by pressurized leaking gas. In some applications, acoustic gas detection is faster than other fixed gas-detection technologies because acoustic detectors do not have to wait for gas to contact them in order to "hear" a leak. Acoustic detectors are generally unaffected by rain, fog, wind or extreme temperatures, making them suitable for harsh outdoor environments (Figure 8).

Along with these advantages, however, come some limitations. For example, acoustic detectors cannot distinguish specific gas types. Nor can they detect toxic parts-per-million concentrations or the lowest gas concentration capable of producing a flash of fire in the presence of an ignition source (LFL). Therefore, acoustic detectors are best used as a complement to other gas detection methods.

When selecting an industrial acoustic gas detector, look for a high-fidelity microphone capable of continuously checking for the distinct ultrasound emitted by pressurized gas leaks across the widest spectrum of frequencies, while ignoring nuisance ultrasonic sources in the environment that could cause false alarms. The detectors should also require minimal maintenance and be SIL 2-capable for all gas types.

Putting it all together

While gas-concentration monitors keep tabs on process gas in a chemical plant, risk-mitigation gas detection systems are on the alert for gas leaks that could pose a danger to plant personnel. These life-safety systems mitigate risks stemming from leaks of both toxic and combustible gases, help prevent explosions and harm to workers caused by leaking gas, and in turn, reduce costly downtime.

When considering the purchase of detectors and other components that make up a gas-detection system, it is natural to look for ways to reduce the cost of the system. Use caution in this regard, though, because cutting the cost of the life-safety gas system you specify could increase risks to your facility and workers. Specifying and installing the right combustible- and toxic-gas detectors — with appropriate product approvals and performance certifications — ensures that your gas detection system will mitigate risk as intended. ■

Edited by Mary Page Bailey

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The annual Water Environment Federation Technical Exhibition and Conference (Weftec) is taking place Sept. 29—Oct. 3, 2018 in New Orleans, La. The event will feature an extensive program of technical sessions and workshops all focused on water management. Over 900 exhibitors will be showcased at the tradeshow. The following preview highlights a small sampling of these exhibitors' products and services.

Flottweg

Economic solution for sludge dewatering

The new Xelletor Series of sludge-dewatering decanters is designed to dry sludge more efficiently and reduce disposal costs for treatment-plant operators. The decanter features a uniquely designed rotor and scroll, and consumption of polymer flocculant is significantly reduced, due to an entirely new intake configuration. Depending on sludge quality, the device can save about 20% on energy and polymer consumption, increase throughput by up to 15% and reduce the volume of biosolids by as much as 10%, according to the manufacturer. The Series' extra-deep pond concept further contributes to energy savings. Compared to conventional high-performance centrifuges, the Xelletor can achieve a 2% increase in dry-matter content, reducing overall sludge volume. Booth 6439 — *Flottweg SE, Vilsbiburg, Germany*

www.flottweg.com

HRS Heat Exchangers

Demonstration of a new effluent-concentration system

This company will debut a trial version of its effluent-concentration system (photo), which enables plant operators to measure how much their effluent waste volumes can be reduced before committing to a full-sized system. By using evaporation to increase the dry matter content of digestate (typically from 2% to 10%), the concentration system reduces the volume of liquid digestate by around 80%, while at the same time increasing the nutrient content. This means up to 80% less digestate storage capacity and lessened transportation loads, helping to curb a plant's operational costs and carbon footprint, while creating a richer biofertilizer, says the company. Furthermore, the water removed by the process is recovered and mixed with the plant's feedstock, increasing the efficiency of the digester and reducing the amount of energy and water used by the plant. The system can also be used to concentrate other industrial effluent waste streams, such as leachate. Booth 3257 — *HRS Heat Exchangers Ltd., Hertfordshire, U.K.*

www.hrs-heatexchangers.com

GF Piping Systems

Increase pump lifetime with this conveying technology

This company's Smart Conveying Technology (SCT) features an integrated tensioning device and enables a pump's rotor-stator sealing line to be adjusted to suit the application and compensate for wear, leading to significantly longer rotor and stator lifetime. SCT can also shorten the time required for maintenance activities by as much as 85%, says the manufacturer. Furthermore, maintenance is made easier due to the system's two-piece Smart Stator and quick-release Smart Rotor, which leave the joint in place and eliminate the need to remove pipework. Booth 6939 — *Seepex Inc., Enon, Ohio*

www.seepex.com

Measure free chlorine without the need for reagents

The 4630 chlorine analyzer (photo) offers a turnkey solution for accurately measuring free chlorine. Its amperometric sensing technology provides an improved solution over traditional chlorine monitoring by enabling more accurate measurement in realtime and eliminating the need for reagents. Typical uses include primary or secondary disinfection, water distribution, dechlorination, algae growth prevention, slime (biofilm) control and taste and odor control. The 4630 incorporates a clear flow cell, flow regulator, sensors, filter and rotameter all in one compact unit. Other features include pre-wired electronics, a 120-V a.c. power plug, two 4–20-mA outputs, two mechanical relays and the ability to have continuous pH compensation that allows for accurate free chlorine readings. Diagnostic data can be easily accessed for troubleshooting purposes. Booth 2551 — *GF Piping Systems, Irvine, Calif.*

www.gfps.com

Dual storage silos for dry bulk materials provide flexibility

This company has introduced new dual dry-bulk-chemical storage silos with integral feeding and dissolving systems (photo) that can be used to reduce the overall height profile of a single high-rate application or to feed two different chemicals to one or more application points. The dual silos are typically mounted close enough to each other to allow for a single ladder with a safety cage to access one silo roof, and a catwalk spanning the two silos to allow for access to the second roof. Fill lines are routed to a single loading point, with a single truck-fill panel operating both systems. A security keypad, wired to automatic valves on the fill line, ensures that dry chemicals are being delivered to the correct silo. Custom control packages and ancillary equipment are also available with the system. Controls are typically located inside the skirted silo, along with necessary piping and wiring, requiring minimal installation of some external components. Booth 4541 — *Acrison, Inc., Moonachie, N.J.*

www.acrison.com

This check valve provides rapid dispersion of head pressures

The ProFlex 790 low-headloss inline rubber duckbill check valve (photo) features a unique design that provides rapid dispersion of head pressures, and features low cracking pressure to prevent upstream flooding. The fold-away design of the inner sleeve also allows for a near full-port flow, allowing for quick drainage. The inline design of the check valve allows for installation without modification to existing structures. The design of the ProFlex 790 makes it suitable for many applications, including combined sewer overflows, sanitary sewer overflows and outfalls. Booth 3118 — *Proco Products, Inc., Stockton, Calif.*

www.procoproducts.com

Corrosion-resistant scales and feeders

This company has introduced a line of volumetric screw feeders that includes an automatic metering screw feeder (photo) for dispensing dry powdered or pelletized materials, such as alum, carbon, lime, polymers, potassium, soda ash and more, into a secondary process. The feeder includes a rugged steel frame with a corrosion-resistance protective finish. Feeders are available with an optional gravimetric feeding configuration with integrated loss-in-weight system. Equipment is rated as water- and dust-proof per NEMA 4X requirements. Booth 2339 — *Scaletron Industries, Ltd., Plumsteadville, Pa.*

www.scaletronscales.com

Acrison

Proco Products

Scaletron

Water disinfection with dry calcium hypochlorite

Constant Chlor water-treatment systems use dry calcium hypochlorite and are designed as an alternative to gas or liquid chlorination. The Constant Chlor product line features a patented spray technology and is fully customizable. It can be installed as a standalone system or be integrated with other process and control equipment. The Constant Chlor Model MC4-50 feeder (photo) sets itself apart from typical erosion feeders due to its spraying process that dissolves materials from the bottom of the briquette bed. The feeder is NSF/ANSI 61 certified to prepare and automatically deliver a consistently accurate dose of liquid-available chlorine for drinking water applications. Constant Chlor Plus

Lonza Water Treatment

briquettes are designed specifically for use in Constant Chlor feeders, and are NSF 60 certified for use in drinking water. These pillow-shaped briquettes create a well-packed spray bed, compared to generic tablets that leave gaps, says the manufacturer. Booth 1644 — *Lonza Water Treatment, Alpharetta, Ga.*

www.lonzawatertreatment.com

Safe containment of hazardous and corrosive chemicals

Assmann

This company provides a full line of corrosion- and chemical-resistant tanks and containers (photo) constructed from crosslinked or linear polyethylene, including vertical, horizontal and conical, and other double-wall tanks, secondary containment basins and chemical feed stations in capacities ranging from 40 to 12,000 gal. Linear polyethylene tanks are certified to NSF/ANSI Standard 61 for potable water and the high-density crosslinked resin tanks are certified by NSF for chemical storage. The line includes a small double-walled tank that is specially designed for primary and secondary containment of hazardous and corrosive chemicals in a single unit. These tanks are available in sizes from 20 to 405 gal. Booth 2552 — *Assmann Corp. of America, Garrett, Ind.*

www.assmann-usa.com

Mary Page Bailey

Co-located Facilities: Untangling Environmental Compliance, Liability and Accountability Issues

When multiple operators, co-owners, co-operators and third-party contractors are all managing different engineered systems at the same location, extra care is needed to manage potential environmental issues that may arise

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The obligations facing facilities throughout the chemical process industries (CPI) related to state and federal environmental laws, regulations and permits continue to be both complex and significant. The operational and regulatory complexity is compounded for facilities that have multiple owners and operators inside a single fenceline. In fact, such scenarios can give rise to some of the most challenging issues that exist under environmental law. CPI companies that have multiple entities operating at their facilities must carefully consider different potential environmental scenarios that could arise, to evaluate how well their systems would function under the circumstances, and to ensure that their contractual arrangements with the other entities are clear and robust and that there are strong, well-tested understandings of how those arrangements are to be implemented, especially in the event of a significant incident.

The basic environmental law framework. Examining the primary federal and state environmental statutes related to clean air and water, waste management and more, it is clear that the U.S. Congress had in mind a world in which the owner or operator of a facility or entity generating a regulated emission or waste stream would be the one legal "person" responsible for obtaining permits, implementing pollution controls, ensuring the performance of protective work practices and the like. The National Pollutant Discharge Elimination System (NPDES) permitting regulations under Section 402 of the U.S. Clean Water Act provide just one example of this — "owners and operators" of a "point source" must obtain a permit to discharge pollutants. Perhaps in the 1970s and 1980s, the ownership and operation of major industrial facilities was mostly unitary and that legal approach was representative of the world it purported to regulate.

Modern commercial and physical arrangements. Today, however, real-world industrial operations are vastly more complex and integrated than that original "owner/operator" scheme presumed. Today, there are many different commercial and physical arrangements at work in modern CPI sites. Individual industrial units within a single fenceline are now often owned or operated by multiple entities following transactions, joint ventures, tolling arrangements and spinoffs that have occurred with increasing frequency at multi-product chemical-manufacturing and petroleum-refining complexes.

Many of these facilities also now encompass production units integrated with large-scale support services, such as cogeneration facilities for steam and electricity production, industrial gas systems, and chemicals-management and storage systems. These support services, which are often industrial-scale activities in their own right, are commonly outsourced to third parties whose own employees and equipment are present inside the larger facility complex. Typically, such third-party vendors also manage very large, heavily regulated repair, maintenance, waste management, testing, cleanout and other functions as independent contractors to the facility's owners and operators.

Modern arrangements increase legal complications. In many scenarios, these new arrangements create significant additional complexity under the "owner/operator" framework of most of today's environmental laws. In wastewater and stormwater discharges, for example, where multiple parties operate inside a single fenceline (and each handles a variety of products and materials

Many CPI facilities operating within the same fenceline are now owned or operated by multiple entities (following transactions, joint ventures, tolling arrangements and spinoffs)

that could wind up in the site's discharge streams), questions inevitably arise as to who should be responsible for permitting, monitoring and ensuring compliance related to those discharges. Presuming (as is typical) that the company that owns and operates the outfalls is the permit holder, rather than each operator establishing its own dedicated discharge system and then obtaining its own separate permit, it is a reality — however unfair — that the permit holder is legally responsible if unauthorized materials end up in the discharge as a result of another party's spills or leaks. Sorting out (among the various operators) how such circumstances should be handled in advance — in terms of, for instance, what protective practices will all parties pursue, to whom do reports of spills get made, who pays the penalties if enforcement occurs — is clearly a complicated and resource-intensive undertaking.

Other environmental scenarios

The U.S. Environmental Protection Agency (EPA; Washington, D.C.), for example, takes the position that many persons can be the "generator" of a waste produced at a facility. Under U.S. Resource Conservation and Recovery Act (RCRA) regulations, a regulated "generator" is "any person, by site, whose act or process produces hazardous waste" or "whose act first causes a hazardous waste to become subject to regulation." Imagine the scenario where a vendor is engaged to remove sediments from a hazardous-storage tank. The person who owns the tank and the product contained in it would be a generator, but so would the vendor, whose act (removing the sediments from the product tank) would cause the sediments to be subject to regulation. While EPA recognizes this complication and encourages parties in circumstances like these to enter into "co-generator agreements" that allocate responsibility for different wastes, if the party contractually obligated fails to comply, EPA reserves the right to enforce against everyone who meets the definition of "generator."

In the clean air context, obligations are determined in part based on the quantity of emissions released into the environment by a facility. Major sources — defined in the U.S. Clean Air Act as a stationary source with potential emissions exceeding certain tons-per-year thresholds — are obligated to obtain additional permits and are subject to more stringent requirements; smaller emissions sources, while still subject to regulation and normally requiring agency authorization, often face fewer re-

quirements. Where multiple companies operate emissions-generating units at a single CPI complex, questions may arise as to whether and how to aggregate their emissions to determine if the facility qualifies as a single major source, or if there can be multiple, less-regulated minor sources inside a single fenceline.

Additionally, when permitting air emissions sources, it is typical for agencies to require modeling that would show anticipated impacts to the nearest third-party "receptors" in order to determine what emissions levels are protective of those receptors. If your nearest receptor is only a few hundred feet away inside the same fenceline, instead of outside the complex fence, your modeling will dictate much more stringent controls. Many of the environmental agencies recognize this concern and allow multiple inside-the-fence entities to designate the larger complex as a single facility for purposes of such modeling (that is, to disregard each other as receptors), using a mechanism often referred to as a "single property designation." However, the contractual arrangements between entities intended to achieve that result may not always be straightforward.

Clean air complexities also arise in the context of Title V deviation reporting. For example, cogeneration facilities that supply power to neighboring operational units within the same fenceline occasionally experience power failures. Those failures will typically cut power to the co-located, downstream operational units. Almost invariably, this leads to unplanned emissions, which wind up in the semiannual deviation reports that are required of major point sources. Permits provide no protection in this scenario because unplanned emissions cannot be permitted. Worse, the affected operational units often bear the brunt of enforcement. Regulatory agencies rarely accept no-fault defenses in this context, even if comprehensive mitigation efforts are deployed to manage the power outages. This leaves the affected operational unit to deal with the enforcement action and penalties.

Statutes like the Toxic Substances Control Act (TSCA) and the Emergency Planning and Community Right-to-Know Act (EPCRA) are just as tricky. Reporting requirements related to the handling and storage of hazardous chemicals are often triggered by the storage, processing or release of hazardous substances in particular quantities. Are the chemicals in question to be aggregated facility-wide, or only counted entity-by-entity for purposes of establishing these thresholds? And who is legally responsible for reporting, and under which circumstances? If there is a reportable release or, unfortunately, a more serious incident such as a fire, explosion or natural disaster involving one or more entities inside the complex fence, who has incident command, and under what circumstances? Who is responsible for notifying the relevant agencies and who will interface with those agencies when they arrive at the facility?

Recent hurricanes highlight

broader operational complexities that can arise when natural disasters strike. Hurricane Harvey, for example, drenched many highly integrated petroleum refineries and petrochemical complexes along a swath of the U.S. Gulf Coast, with record-setting rainfalls. As a result, many facilities scaled back or completely shut down production units. These scale-backs and shutdowns are not trivial. They require detailed engineering and business planning and training, and the disruptions force operators to make difficult decisions with potentially significant environmental consequences.

Co-location and integration with third-party suppliers compound these challenges. What are the site-wide consequences if certain suppliers go offline or if only certain operators scale back or shut down production? How are those consequences addressed and managed? These types of questions illustrate the potential complications that become necessary to vet as an operator implements its natural-disaster -response strategy.

Process safety management and risk management plan (RMP) implementation force similar evaluations. Under EPA's RMP rules, operators must determine what processes are covered by the regulations. Some RMP rules apply to entire facilities, while others only apply to certain processes.

The RMP regulations also permit a degree of flexibility to develop a risk-management process that fits the facility. Typically, regulatory flexibility is viewed as beneficial by the regulated community. But the RMP program's regulatory flexibility might sometimes be more of a bane than a boon. Different operators within a co-located facility likely use the flexibility within the rules to write RMPs that best fit their processes. Individually, this may be fine. Collectively, however, those RMPs could result in a hodge-podge of procedures that may not synchronize in a way that leads to efficient, coordinated response actions.

And while not environmental law per se, in the related worker safety context, the U.S. Occupational Safety and Health Administration (OSHA; Washington, D.C.) has long recognized the complications of so-called "multi-employer worksites" and developed guidance on which employers are subject to enforcement for regulatory violations at such sites under what circumstances. If agencies can recognize and plan for the tricky circumstances these co-located arrangements give rise to, then industry certainly can, as well.

Developing key arrangements

Most often, in standard operating scenarios, multiple operators that are co-located and co-integrated within a single facility have general guidance and mutual understanding of who is responsible for what. Complications in those relationships most commonly arise in non-routine scenarios where something has gone wrong — whether it's an operational challenge, a noncompliance, an incident or accident, or attention from regulatory enforcement officials. In those circumstances, finger pointing and disagreements can begin. If the relative responsibilities of the different parties are not clear, that can lead to significant disputes and, in the interim, mistakes being magnified while none of the parties are willing to undertake the necessary efforts to correct a problem.

Unfortunately, in some cases, the contractual agreements between parties operating together inside a single industrial facility are often as simple as the legacy party retaining responsibility for pre-existing conditions and the parties agreeing going forward to each be responsible for their own compliance. As suggested above, the scenarios where things can go wrong often arise where both parties have underlying legal obligations, where responsibility is unclear or disputed, and where the entity with the greatest ability to control a problem may be an entity that was not responsible for the problem in the first place. In these circumstances, a "my stuff/your stuff" contractual allocation of responsibility is far from adequate.

The better approach to such allocations is to have the environmental experts and counsel with each relevant company carefully discuss the major applicable requirements and how they are implemented. They should also imagine the primary foreseeable circumstances that could lead to those companies having potentially overlapping responsibilities or trigger a need to work together in order to develop and implement solutions that are most favorable to all concerned.

Once areas of overlap are identified and a list of such scenarios is developed, companies should consider pursuing tabletop-style exercises or drills to better understand who needs to be involved, and when, which issues are most likely to lead to confusion or disagreement, and how those issues are likely to arise in the most probable or highest-stakes scenarios. Once those understandings are reached, operators are in a better position to plan for those scenarios together, to clarify who is responsible for what and when, and to codify those responsibilities in contractually enforceable language.

Proactive efforts save time and resources and will promote more efficient responses to events that trigger co-location and co-integration issues. Plant personnel and support staff will be able to resume their work more quickly. Getting bogged down in the blame game or post-incident allocation negotiations only distracts from the real task at hand — ensuring safe, reliable production. ■

Edited by Suzanne Shelley

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Water Management

special advertising section

CHEMICAL ENGINEERING
ESSENTIALS FOR THE CPI PROFESSIONAL
Access Intelligence

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Engineered Solutions For Compact Spaces

New Electronic Valves and Pressure Regulators from Valcor Engineering Corporation for Use in Space Constrained Manufacturing Environments

Valcor Engineering Corporation, a designer and manufacturer of solenoid valves and control components for liquids and gases, has recently debuted their new electronic valve and pressure regulator lines. These new products (SV102 regulator and SV22 and SV28 electronic valves) allow them to engineer solutions into a compact space at a cost-effective price.

The SV102 is a manual regulator that provides great accuracy and repeatability in a compact, durable package. It is suitable for a variety of industrial applications, both new and retrofit. Typical applications include: pressure control of inks and tones in printing applications, inert gas pressurization of reaction vessels, controlling flow of process gasses in packaging applications, and varied other uses in food processing, pharmaceutical and manufacturing fields.

The SV22 and SV28 have a cycle-life of over a billion cycles offered in a solid, compact design with extremely high flow rates. These valves are suitable for many applications across numerous industries requiring minimal downtime for maintenance.

The SV22 comes in 2-way and 3-way configurations and can be used in many applications, including inert gas controls in packaging applications, BP cuff inflation control, CPAP devices, seal inflation control, air pilot control, weld shielding gas control, filling and dispensing, reagent control, rinsing/CIP applications, and process fluid control.

SV102

SV22 & SV28

The SV28 utilizes the latest technology to provide gas flow control. The operator is able to vary the output flow based on the current input to the solenoid. The consistent gain and low hysteresis of this valve provides a high degree of controllability. The valve may be controlled using DC current, open or closed-loop control, and even pulse width modulation to cover a wide range of applications.

Valcor Engineering Corporation designs and manufactures solenoid valves and control components for liquids and gases in critical applications in the aerospace, nuclear, light industrial and scientific industries. Founded in 1951 and headquartered in Springfield, New Jersey, Valcor's staff of engineers, designers, and technical support personnel utilize fully-equipped, modern test facilities to test the most precise and exacting standards.

www.valcor.com

Plastic Diaphragm Valves

GEMÜ leaves nothing to chance in the development and manufacture of plastic diaphragm valves

Areas of application and industrial sectors

GEMÜ plastic diaphragm valves are available with a variety of high-quality plastic body materials and connections. The plastic diaphragm valves support a large range of industries and applications including water treatment, chemical, environmental systems, power generation, solar, semiconductor, microelectronics, food and beverage, and processing just to name a few. Many of the plastic diaphragm valves are supported by an extensive line of pneumatic operators that can be fully integrated into automated systems allowing industries to save time and money on their operations, while increasing accuracy and efficiency in their performance.

Diaphragm Valve Design

The structure and function of the diaphragm valve is that of a completely enclosed connection with a weir and short intercepting shaft that accommodates the operation of a mobile seal identified as the diaphragm or membrane. This diaphragm is the essential part of the valve that controls the movement of media through the system the valve is integrated into. The diaphragm valve operates by pressing the diaphragm tightly against the weir, making a fluid tight seal restricting movement of media flow. Alternatively, the diaphragm is lifted away from the weir to allow partial to full media flow. Operation of a diaphragm valve is very simple as it is the accommodation of various stages of full or restricted media flow.

GEMÜ leaves nothing to chance in the development and manufacture of plastic diaphragm valves. The plastic diaphragm valve is designed with the challenges of friction, turbulence, debris and trapped air in mind. The GEMÜ plastic diaphragm valve is flow-optimized by incorporating a smooth media transition structure which allows low friction, low turbulence of media and leaves no offsets that cause the collection of air pockets and debris in the system.

Additionally, GEMÜ plastic diaphragm valves utilize highly durable, low maintenance pneumatic membrane actuators that give precise flow control in high cycle operation.

GEMÜ Plastic Diaphragm Valves

The GEMÜ Plastic Diaphragm Valves are available with additional considerations to industry needs that include having the same mounting height planes over multiple nominal sizes, compact plant design, reduced control air consumption needs for the pneumatically operated valves and a variety of optional accessories for measurement and control.

www.gemu-group.com

CR Clean Scrubbers tackle a wide range of applications

From odor mitigation to acid gas removal, CR Clean Air has the solution to meet almost any emission challenge.

CR Clean Air has been providing wet scrubbing systems across a wide array of process industries for almost 70 years. From the initial jet venturi fume scrubbers they developed in the 1950's to the fully skidded packages they offer today, CR Clean Air has always been driven by engineering the best possible solution to meet a plant's emission control needs. Experienced in a wide range of applications, be it odor mitigation by removing H2S and mercaptans, control of acid gases such as HCL and SO2, and even the removal of fine and sub-micron particulates from a contaminated vapor stream, CR Clean Air's depth and breadth of experience is unmatched. As a leader in clean air technology, they have been at the forefront of dealing with many complex chemistries and challenging pollutants, from ethylene oxide to NOx emissions.

CR Clean Air's has the experience to engineer a system that will work the first time, and its commitment to quality ensure that it will continue to work for decades to come – be it a standby scrubber to handle an emergency release of toxic vapor to an odor control unit that needs to run 24-7. From small manually controlled units to large fully automated systems with complex instrumentation and built in redundancy, their team of electrical, chemical and mechanical engineers are able to assist in developing customized solutions. Their offerings are available in a wide range of materials, both metal and non-metal, including carbon steel, stainless steel, corrosion resistant alloys, FRP, Polypropylene, PVDF and dual laminates.

CR Clean Air has systems installed across a wide range of industries - Aerospace, Chemical, Municipal waste water, Pharmaceutical, and Pulp & Paper just to name a few. The range of pollutants is also as varied, including HF, HBR, NH3, Silicates, dust and certain VOC's. CR Clean Air has a range of approaches in its arsenal, from water once through to chemically scrubbed system complete with recirculation.

From Arsenic to Zirconium Tetrachloride ... CR Clean Air scrubs gasses others won't touch. For more information on how a CR Clean Air scrubber fits into your plants environmental compliance please contact them at info@crcleanair.com

www.CRCleanAIr.com

Flottweg Separation Technology – Engineered For Your Success

Flottweg is one of the world's leading manufacturers of industrial centrifuges. The company, headquartered in Vilsbiburg, achieves an annual turnover of over 169 Million Euros with an export rate of more than 85 %. Flottweg has own subsidiaries and branch offices with service centers in the US, in People's Republic of China, in Russia, Italy, Poland, France, Australia and Mexico. Concentration on customer requirements, keen sense on how markets will develop, and the ability to come up with creative solutions have helped to make Flottweg one of the world's leading producers of centrifuges for separation technology. In order to secure the market position for the future, Flottweg will continue to upgrade its technology, provide the highest quality products and provide 24-hour aftermarket service.

OUR MACHINES: Flottweg **Decanter**: Hygienic, gas-tight (Atex) and wear-protected according to the application. Flottweg **Sedicanter®**: The ideal connection of disc stack centrifuges and decanters, for highest separation and yields. Flottweg **Tricanter®**: Continuous threephase separation in one step, economic and efficient. Flottweg **Sorticanter®**: Unique decanter for continuous separation of plastics. Flottweg **disc stack centrifuges**: Fully automatic disc stack centrifuges for clarification and separation, efficient and effective. Flottweg **belt presses**: Continuous pressing of mashes and dewatering of solids – high yields and high cake dryness, low operating costs.

www.flottweg.com

Handling Corrosive Water with Kynar® PVDF

Double diaphragm pump made using Kynar PVDF available in many sizes

Wastewater generated in chemical processes can create difficult challenges for standard materials of construction. The combination of many different acids, chlorides, bases, and solvents can quickly oxidize and corrode common metallic materials and severely soften, swell, or crack traditional polymers. Fluid handling components made from **Kynar** PVDF and Kynar Flex PVDF have been used for many years in the most demanding applications.

The broader range of chemical resistance of Kynar PVDF compared to other polymer materials has led to complete product lines of piping, fittings, tubing valves, pumps, tanks, nozzles and filtration components that can be employed to handle varied concentrations of some of the most aggressive corrosive chemicals. In addition to the excellent chemical and permeation resistance, Kynar PVDF is 150°C RTI rated, ASTM E84 (25/50) compliant, inherently sunlight resistant, and highly abrasion resistant. Due to the thermoplastic nature of Kynar PVDF, it is light weight and very easy to fabricate by common heat methods like welding and thermoforming. Mechanical joining methods and threading are also possible.

Examples of Kynar PVDF in waste drain and exhaust systems span several industrial market segments.

- Petrochemical – combinations of aromatic and aliphatic hydrocarbon mixtures including sulfur, brines, and acids
- Food & Beverage – chlorinated cleaning agents, acidic sanitization chemicals, and alcohols
- Nuclear Clean Up – acids, radioactive materials, and chlorinated water
- Biotech & Pharmaceutical – Bromides, chlorides, acids, and alcohols
- Pulp & Paper – bleaching chemicals, acids, and brines
- Mining & Metal Preparation - hot acids
- Semiconductor – peroxides, acids, and sulfate solutions
- University Laboratories – ASTM E84 flame and smoke compliance, virtually unlimited chemical combinations

Solid or supported piping systems with various joining methods are readily available up to 12 inch diameter, and these are complemented by multiple types of valve and pump designs made from Kynar PVDF to connect the whole system. Holding vessels or other containment items can also be constructed by rotomolding or by welding sheets of the required thickness together.

Pipes made from Kynar PVDF installed in hot mixed acid application

PVDF is the only Fluoropolymer available with a very broad range of stiffness options for anything from highly flexible tubing to rigid self-supporting pipes. New grades of glass fiber composites called Kynar UHM PVDF can increase the already high strength of the base material by up to 3 times higher flexural modulus. These grades are being used for fasteners, pump bodies and structural supports in fluid separation.

www.kynar.com

The key to your reliable and individual solution

Industrial plants all over the world are provided with gaseous media using **AERZEN** blowers and compressors. The innovative AERZEN machine technology represents experience of more than 150 years company history. The range of products includes rotary lobe compressors, positive displacement blowers, turbo blowers, screw compressors and gas meters. AERZEN blowers, compressors and gas meters are tested and certified according to DIN EN ISO 9001. There is a variety of product offerings from standard products to customised solutions.

When it comes to your best solution, you should be as uncompromising as we are: It must be precisely tailored to your requirements, absolutely reliable and highly efficient. With individual assembly configurations and customised services, AERZEN has been serving demanding process applications worldwide for over 150 years. Thanks to efficient compressors and blowers, comprehensive engineering knowledge and pronounced consulting competence, AERZEN can implement your individual customer requirements exactly. In addition, the AERZEN After Sales Service offers the complete range of services - from the full maintenance contract to repairs and upgrade of existing plants.

Compressed air, gas and vacuum solutions are part of our business. Please visit www.aerzen.com and learn more about the unique variety of AERZEN technology. **www.aerzen.com**

Catering for clean water

AUMA's high-performance electric valve actuators prove their performance in industrial water treatment

AUMA electric valve actuators have a strong background in industrial water and wastewater treatment, including ZLD facilities.

With more than 50 years of experience in supplying reliable and rugged valve automation solutions, **AUMA** offers electric valve actuators that meet the most demanding requirements for process water and industrial wastewater applications.

"The requirements for industrial wastewater purification are getting more and more stringent in many countries," says Marc Schmidt, Head of Sales Water at AUMA. "AUMA actuators are proving their performance in industrial water treatment projects around the world, in industries from pharmaceuticals and chemicals to microelectronics and mining. They also meet the challenging requirements of zero liquid discharge (ZLD) facilities, supporting advanced treatment technologies such as reverse osmosis (RO)."

A worldwide installed base of several hundred thousand actuators in water and wastewater treatment confirms the toughness and reliability of AUMA's flagship SA multi-turn and SQ part-turn actuators. They feature a robust design, long service life, IP 68 enclosure protection and maximum corrosion resistance, meeting C5-M and C5-I requirements according to EN ISO 12944-6. Integral controls add powerful diagnostics and datalogging, with easy DCS integration via fieldbus or Industrial Ethernet communication.

Modular design and a wide range of actuator sizes and options offer automation solutions for any type of valve. Special modulating duty and variable-speed versions provide maximum positioning accuracy and high operating speed. **www.auma.com**

Economic Mixing Solutions for Water and Wastewater Treatment

Special impeller for operation in sludge containing long fibers

EKATO EM 2000 / EKATO AQUAJET B impeller

EKATO`s offer:

- Expertise knowledge for your minimum process design requirements
- Detailed process development for water, waste water and biological sludge applications
- Success experiences in plant scale
- Corrosion resistant coatings to meet your compatibility needs

Advantages:

- To minimize the motor power and the cost of operation
- Safe and reliable mechanical mixing agitator design

Treatment of Drinking Water:

- Continuous operating cleaning processes with high flow rates
- The mixing tasks are:
  - To achieve a sufficient homogeneity of the reactants at a given middle resistance time
  - To support the precipitation-coagulation
  - To avoid any damage of the formed flakes in the flocculation step

Treatment of Waste Water Sludge in Fermenters (Digesters):

- In large reactor vessels, (>1000 m^3) has to blended viscous sludge with about 2-8% organic solid content
- Avoid settlement particles at the bottom of the vessel
- Reduction and incorporation of dry solid layers on top of the liquid. The layer arises due to the drying effect caused by the methane gas flow out of the liquid surface
- Handling of sludge that is contaminated with long fibers which can agglomerate at the impeller
  The complete agitator can be destroyed due to resulting shaft deflection. Using the **EKATO-Aquajet B** does solve this problem.
- **The EKATO-EM 2000** agitator series has several mechanical seal types to handle the explosive conditions

www.ekato.com

Accurate Flow Measurement Helps Optimize Water Management

In today's demanding business environment, the chemical processing industry (CPI) is facing a host of new challenges. It needs to achieve mass production and economies of scale in a market that is constantly evolving.

Water is an important raw material for chemical and petrochemical plants. Efficient management of the industrial water cycle can affect production performance, operating costs and the environment at every site.

As the limited availability of fresh water resources gains increasing concern around the world, plant managers are focusing more and more on water treatment, re-use and conservation.

Typical Requirements

Flow measurement is a critical aspect of plant operation in the CPI, particularly as it relates to effective water management. Users must consider a wide range of factors to arrive at an optimal solution. There are significant differences between meter technologies, with each type of device having its own advantages and disadvantages for processing facilities.

Most chemical processing plants have two primary flow measurement challenges: accuracy and cost. The goal is to correctly match the right flow meter to the right application to achieve the best performance for the lowest purchase price and total cost of ownership.

Why DP Flow Meters?

Experience has shown that Differential Pressure (DP) flow measurement is a solid performer among flow meter technologies. This is especially true for measurement of water in chemical and petrochemical applications.

There are numerous attributes associated with DP meters: no moving parts, accuracies that rival turbine meters without the need for maintenance, temperature and pressure options galore, and service ranges from vacuum to many thousands of pounds per square inch.

The materials of construction for DP meters are also very flexible. Most companies can manufacture out of whatever material best suits the application.

If desired, most DP meter elements can be flow tested along with their respective transmitters for ultimate performance. Some meter designs can have transmitters directly mounted to the element with suitable manifolding to allow for future calibration checks and service.

Conclusion

Differential Pressure meters can be the best solution for some of today's most difficult CPI flow measurement applications. This technology is a proven problem-solver with versions that are specific to different measurement tasks.

www.badgermeter.com

Cleaver-Brooks Delivers HRSG Solutions

Cleaver-Brooks, a world-renowned source of boiler room products and complete system solutions, is committed to helping its customers and the industry reduce energy usage, costs and environmental impact. As part of its portfolio, the company offers customized, packaged heat recovery steam generator (HRSG) solutions, including its Max-Fire Series, Slant & VC Series and Modular HRSG Series. Each provides a distinctive solution for a wide range of heat recovery applications.

The Max-Fire boiler incorporates an integral furnace in a single, shop-assembled, packaged HRSG design. The use of the unique membrane wall/water-cooled furnace technology allows it to be fired up to 2,800 °F while avoiding the use of high-maintenance refractory. This boiler design allows the user to maximize the steam output from the boiler with a given flue gas input. It is capable of steam flows as high as 300,000 lb/hr.

The Slant & VC Series boilers are ideal for applications where the gas side inlet temperature is less than 1,700 °F. With a single-pass design, this series allows the boiler system to be optimized to fit in a variety of space limitations. With options for a top or side outlet, these boiler systems are designed to maximize operation while fitting in the smallest and most economical footprint. The Slant & VC Series also is suitable for applications where an SCR or CO catalyst must be incorporated to meet today's stringent environmental permitting requirements.

Maximizing shop assembly and minimizing field work, the Modular HRSG Series is designed to accommodate exhaust from combustion turbines greater than 15 MWe output or greater than 400,000 lb/hr of gas flow. It is capable of steam flows from 10,000 to more than 1,000,000 lb/hr.

In addition to its expert engineering and manufacturing teams, the company has a dedicated alliance of factory-trained representatives who can be utilized for commissioning, emergency local service, maintenance and aftermarket support. To locate a representative, visit cleaverbrooks.com or call (800) 296-4110.

www.cleaverbrooks.com

Protect production and people with remote pump monitoring

Whether being used for heating or cooling, as a solvent or diluent, or as part of a washing process, the water delivered by a plant's pumps is typically performing an essential task. Often operating at the heart of critical processes, the failure of these pumps frequently leads to reduced or lost production and increased maintenance costs, as well as the potential for safety and environmental incidents.

Typically, an organization dynamically monitors only its most critical and expensive pumps. Whether due to expense, remote location of devices, or difficulty of installation, continuous monitoring is avoided on the remainder of a plant's pumps in favor of clipboard walk-arounds and periodic handheld measurement. As a result, many pumps run blind, increasing the risk of failures, fires, leaks, and other dangerous situations.

The ability to detect and monitor changes in vibration on any pumps in the plant is critical to avoiding pump damage, environmental incidents, and costly downtime. With **Emerson**'s AMS 6500 ATG with embedded prediction, the engineering requirement and cost of applying predictive technologies is no longer an obstacle to monitoring nearly all of a plant's pumps.

Emerson's AMS 6500 ATG is a stand-alone protection solution that also allows users to cost-effectively introduce prediction monitoring of critical assets from the same system. The AMS 6500 ATG can be set up to deliver a wide range of protection measurements from the field, including all required TSI measurements, which include embedded prediction capabilities such as the impacting or peak-to-peak data used in Emerson's PeakVue technology. With prediction data from PeakVue technology, users can cut through the complexity of machinery analysis to provide a simple, reliable indication of pump health, filtering out traditional vibration signals and focusing exclusively on impacting.

Moreover, advanced prediction functionality is available on top of the predictive diagnostic capabilities within the AMS 6500 ATG. AMS Machinery Manager can communicate with the AMS 6500 ATG via wired or wireless networks, depending on hardware, to provide high-resolution waveform and spectrum analysis, making it simple to extend prediction and protection monitoring to include balance of plant assets in a comprehensive monitoring solution.

As many as 50 percent of machinery malfunctions that lead to downtime are process induced, and 90 percent are predictable, or even controllable. The AMS 6500 ATG provides the impact data with actionable alerts that will help reduce production losses, cut maintenance costs, improve safety, and eliminate incidents to pump management.

For more information visit, **www.Emerson.com/AMS6500ATG**

KROHNE Expands Range of OPTIWAVE Radar Level Instruments

Ideally suited for liquid or solids applications in chemical, petrochemical, mineral industries

Beverly, MA: **KROHNE, Inc.** announces the addition of three 24 GHz and three 80 GHz OPTIWAVE Radar Level transmitters to its product line, which complement the existing 6 GHz and 10 GHz devices. The entire range of OPTIWAVE 2-wire loop-powered FMCW radar level transmitters for liquids and solids is ideally suited to industries from chemical and petrochemical to mining, minerals and metals processing and cover liquid and solid applications.

With the OPTIWAVE 1010 (6 GHz), the OPTIWAVE 5200 (10 GHz) and now the new OPTIWAVE series of 24 and 80 GHz radars, KROHNE offers the appropriate frequency for each application. The new OPTIWAVE 5400 / 6400 / 7400 (24 GHz) and OPTIWAVE 3500 / 6500 / 7500 (80 GHz) radars are each designed for specific industry needs, delivering reliable and accurate level measurement of liquids and solids, even in most difficult applications.

KROHNE offers an extensive choice of process connections starting from ” for each of the new radar level transmitters, as well as Lens, Drop and Horn antennas to suit all process and installation conditions. The OPTIWAVE transmitters offer a measuring range from the antenna edge up to 100 m (328 ft), with accuracy from ±2 mm (±0.08”). The OPTIWAVE transmitters can measure products with dielectric constants as low as 1.4, and feature a quick setup assistant for easy commissioning as well as an empty tank spectrum function for eliminating false reflections.

For more information about the OPTWAVE Radar Level transmitters, visit http://us.krohne.com/en/products/level-measurement/non-contact-level-transmitters/.

About KROHNE

KROHNE is a world-leading manufacturer and supplier of industrial process instrumentation solutions. We have 90 years of experience providing flow, level, temperature, and pressure instrumentation to all industry sectors around the globe. For more information, contact KROHNE at 1-800-FLOWING (978-535-6060 in MA); email: info@KROHNE.com, Twitter at @KROHNE_USA, or visit

www.us.krohne.com

Ultrapen PTBT1 Smartphone/ Tablet Compatible Tester

The Myron L® Company's new ULTRAPEN™ PTBTx™, wireless Pocket Testers are designed to be paired with any Apple® iOS 8+ device via the ULTRAPEN's Bluetooth® BLE transceiver. A free App takes advantage of Apple's iOS GUI to provide easy-to-read displays and a simple-to-use interface. The Bluetooth link means that there are no bothersome wires getting in the way when moving quickly between samples and that paired mobile devices can be held safely away from liquids.

Advanced features include: Automatic temperature compensation; stable microprocessor-based circuitry; user-intuitive design and a rugged, waterproof housing.

Available models:

- ▶ PTBT1 - Conductivity, Total Dissolved Solids (TDS), Salinity, and Temperature measurement with three, selectable solution modes that model commonly encountered water types.
- ▶ PTBT2 – pH and Temperature measurement with 1, 2, and 3 point calibration options.
- ▶ PTBT3 - ORP & Temperature measurement.

Using your ULTRAPEN iOS App:

- Each ULTRAPEN PTBTx can be given a unique name stored in the ULTRAPEN's memory so it is easily identifiable no matter what mobile device is used.
- Measurement locations can be programmed as:
  - o GPS locations that are automatically selected when the user is close to a specific measurement local, or;
  - o Non-GPS locations ideal for applications where the sample sites are too close together for the GPS to discriminate.
- Measurements can be saved to the mobile device's memory including measurement data, ULTRAPEN settings, sample temperature, ULTRAPEN name and measurement location.
- Records can be exported via the mobile device's email function as either .csv, .xls, .xlsx formatted files or using Myron L Company's .mlc, proprietary, encrypted format.
- Stored measurements can be sorted or filtered and then emailed or deleted without affecting other records stored in memory.

Coming Soon:

- ▶ PTBT4 - Free Chlorine Equivalent (FCE™) & Temperature measurement.
- ▶ Android™ compatible App.

www.myronl.com

Decades of Application Expertise

EZstrip transfer pump provides maintain-in-place technology

With a proud heritage of technical innovation, **National Oilwell Varco** (NOV) provides solutions throughout water and wastewater treatment processes.

Backed by strong legacy brands, NOV provides pumping and mixing solutions in various industrial markets around the world. Over time, the company has continually expanded its product lines, creating packaged systems and providing aftermarket support to meet customer needs. Working to understand customers' unique challenges, a comprehensive suite of equipment—including Moyno pumps, screens, and grinders, and Chemineer, Kenics, Greerco, and Prochem mixing equipment—ensures a complete and reliable solution for even the toughest of applications.

RL-3 provides rag-free mixing, minimizing downtime.

Moyno-branded progressing cavity (PC) pumps have provided efficient and reliable fluid transfer to the wastewater industry since 1935. From the maintain-in-place EZstrip transfer pump to the larger 2000 series pump, PC pumps are capable of handling abrasive, solid-laden materials at high flows and pressures. PC pumps can be paired with Moyno grinders, screens, and macerators to provide a packaged solution that helps manage solids and keep pipework free of blockage.

NOV's agitators, impellers, and static mixers are key components in any wastewater treatment process, ensuring effective removal of chemical and biological contaminants prior to discharge into the environment. The RL-3 ragless impeller is specifically engineered to prevent fibrous material buildup, making it ideal for blending and solids-suspension applications. NOV's Chemineer agitator line allows for different drive sizes and variations of speeds, ranging from as low as 1 to as high as 380 rpm. Using process-specific elements in a housing for continuous flow applications, Kenics static mixers use energy from the process stream to provide blending and dispersion with minimal pressure loss.

With this combination of quality mixing and pumping products and a dedicated team of experienced technical support staff, achieving operating performance goals is easier than ever before. From installing equipment on site to assisting with repairs or troubleshooting, a network of highly trained field service technicians is ready to help keep processes up and running. NOV partners with customers throughout the life of their projects.

www.nov.com

New AWWA Standard: Progressive Cavity Chemical Metering Pumps

The American Water Works Association (AWWA) has just released the first edition of the new ANSI/AWWA E200-18 standard for progressive cavity (PC) chemical metering pumps. What does this accreditation mean for PC pumps? Credibility. Bottom line is that this standard demonstrates the quality and reliability of PC pumps for chemical metering applications. All AWWA standards are developed in a rigorous, defined manner with due process to interested parties and stakeholders, ensuring that all views and objections are considered and treated fairly. The result is a true industry consensus that can be trusted and widely accepted.

The environmental industry assumes that chemical metering pumps must always be subject to heavy monitoring, frequent parts replacement, and disposal on a regular basis. Pumps are expected to pulsate, allowing a greater opportunity for unstable flow as operators are forced to over or underfeed chemicals in their process. These practices cause unplanned variances, water quality issues and increased cost and downtime. It doesn't need to be this way. Progressive cavity pumps offer several advantages compared to conventional chemical metering pumps due to accurate, repeatable, low shear metering with laminar flow, minimal pulsations and no vapor lock. Pulsation dampeners can be eliminated and chemical consumption in reduced. Slip is minimized even when fluid temperature, viscosity, or discharge pressure fluctuates. Progressive cavity pumps also wear predictably, so there is no risk for catastrophic failure.

SEEPEX, a leading global manufacturer of progressive cavity pumps with decades of experience engineering systems and controls, has released SEEPEX BRAVO Chemical Metering Systems, a market-driven process control solution. Complete process control is possible with BRAVO because systems are equipped with self-priming, NSF/ANSI 61 certified SEEPEX progressive cavity chemical metering pumps. BRAVO is an integrated, modular and scalable solution used in a variety of industries for disinfection, pH control, flocculation, corrosion inhibitors, oxygen scavengers and containment elimination. These plug-and-play packaged skids minimize time and cost associated with engineering, procuring, assembling, and installing flow control systems. BRAVO can be adapted to any layout and are available in simplex, duplex, or triplex pump configurations for floor or wall mounting. BRAVO is offered with user-customized, color display, touchscreen advanced process controls and handle pressure ratings up to 175 PSI and flow rate capabilities from 0.1 GPH up to 250 GPH.

Learn more at WEFTEC booth#6939

About SEEPEX:

SEEPEX Inc. is an ISO 9001-2008 certified manufacturer and a leading international supplier of progressive cavity pumps, systems, accessories and services. SEEPEX takes a consultative approach to offering innovative products and customized solutions for fluids handling and processing applications in nearly every industry. Contact 937-864-7150, e-mail sales.us@seepex.com or visit

www.seepex.com

Common Causes and Types of Fluid System Leaks

Swagelok delivers the lowdown on leaks and how to mitigate them

Found throughout most plants, fluid system leaks can hinder safety and profitability. That's why it's important to understand how and why leaks occur, how to locate and test for them, and how to develop a strategy to address and reduce leaks plantwide.

To help your team better understand and mitigate leaks, **Swagelok's** field engineers have documented the top three causes of leaks:

1. Unreliable Metal-to-Metal Seals

Making and keeping highly reliable metal-to-metal seals can be difficult, especially over time. Manufacturer guidelines must be followed precisely to avoid leaks when using these "packless" seals. In some cases, you may want to instead use a component featuring an adjustable packing for a more reliable long-term seal.

2. Improperly Installed Tube Fittings

Properly assembling tube fittings will greatly reduce the likelihood of experiencing leaks. Be sure your technicians are trained in how to properly make up a fitting, including orienting the ferrules properly and using a gap gauge to verify the right amount of pull-up.

3. Poor Tubing Selection and Preparation

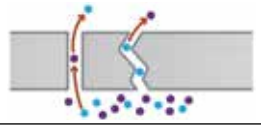
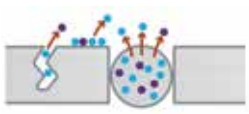
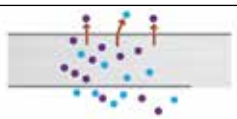
Your tubing selection and preparation can also increase your leak potential. Tubing materials that are incompatible with the process fluid or external environment will be prone to corrosion, premature failure, and leaks. In addition, unevenly cut tubing or tubing with burrs may compromise a fitting's sealing ability.

Get Your Team Up to Speed

Swagelok's training programs help engineers and technicians enhance their skills in identifying and addressing leaks. Training includes everything from material selection advice to hands-on, skill-building courses in tube bending and tube fitting installation procedures. Get your team focused on identifying and stopping leaks, so your plant can realize safer, more cost-effective operations.

Three Types of Leaks

Understanding the type of leak will help your team determine the corrective measures to address it.

	Real Leak: A leak resulting from the failure of a pressure barrier to contain or isolate a system fluid from the surrounding environment; occurs due to cracks or gaps between sealing surfaces
	Virtual Leak: A release of internally trapped fluid into a fluid system due to material outgassing, absorbed or adsorbed fluids, entrapment in cracks, or deadlegs
	Permeation: The passage of fluid into, through, and out of a pressure barrier having no holes large enough to permit more than a small fraction of the molecules to pass through any one hole

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Economic Indicators

2016 2017 2018

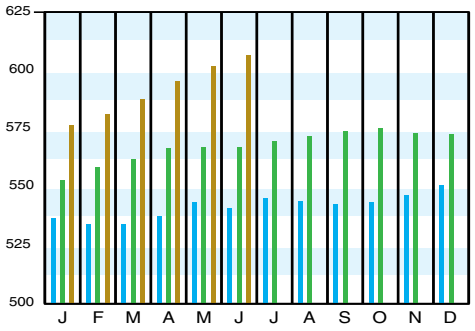
Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	June '18 Prelim.	May '18 Final	June '17 Final
CE Index	606.4	602.9	566.6
Equipment	739.9	735.2	683.2
Heat exchangers & tanks	657.4	653.3	602.8
Process machinery	719.6	718.6	681.5
Pipe, valves & fittings	967.7	958.6	867.3
Process instruments	428.0	422.6	403.6
Pumps & compressors	1017.9	1022.9	985.1
Electrical equipment	536.2	534.0	513.4
Structural supports & misc.	807.8	799.8	737.4
Construction labor	332.3	331.7	327.2
Buildings	600.8	594.4	559.6
Engineering & supervision	307.8	307.7	312.9

Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

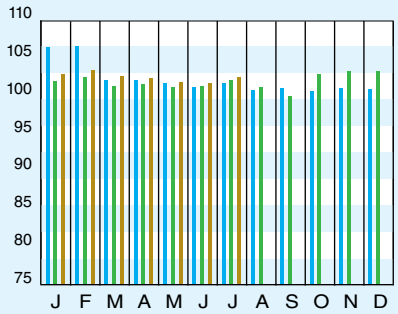
Annual Index:
2010 = 550.8
2011 = 585.7
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5



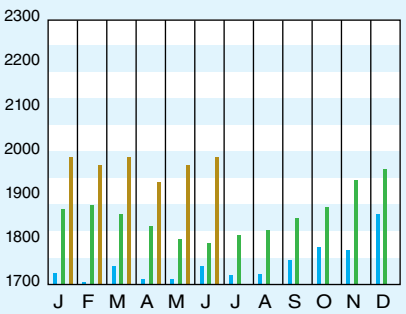
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS		YEAR AGO
CPI output index (2012 = 100)	Jul. '18 = 102.5	Jun. '18 = 102.1	May '18 = 102.1	Jul. 17 = 100.5
CPI value of output, $ billions	Jun. '18 = 1,989.4	May '18 = 1,973.6	Apr. '18 = 1,940.4	Jun./17 = 1,739.8
CPI operating rate, %	Jul. '18 = 76.3	Jun. '18 = 76.0	May '18 = 76.1	Jul. 17 = 75.7
Producer prices, industrial chemicals (1982 = 100)	Jul. '18 = 277.8	Jun. '18 = 273.9	May '18 = 267.7	Jul. 17 = 247.3
Industrial Production in Manufacturing (2012 =100)*	Jul. '18 = 104.6	Jun. '18 = 104.3	May '18 = 103.4	Jul. 17 = 101.7
Hourly earnings index, chemical & allied products (1992 = 100)	Jul. '18 = 182.4	Jun. '18 = 183.8	May '18 = 184.0	Jul. 17 = 179.8
Productivity index, chemicals & allied products (1992 = 100)	Jul. '18 = 96.5	Jun. '18 = 96.5	May '18 = 96.9	Jul. 17 = 98.8

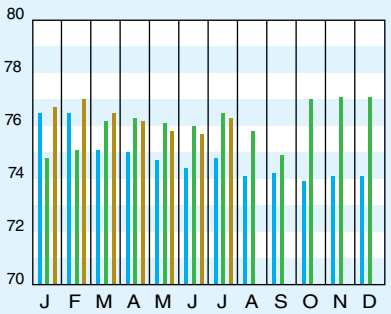
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the June 2018 *CE* Plant Cost Index (CEPCI; top; most recent available) once again increased compared to the previous month's value, continuing a string of monthly increases since the beginning of 2018. All four of the major subindices — Equipment, Buildings, Construction Labor and Engineering & Supervision moved higher for June, with the largest increases in Buildings and Equipment, and smaller increases in the other two subindices. The overal CEPCI for June stands at 10% higher than the corresponding value from June of last year. Meanwhile, the Current Business Indicators (CBI; middle) saw the June value for the CPI output index rise slightly compared to last month.